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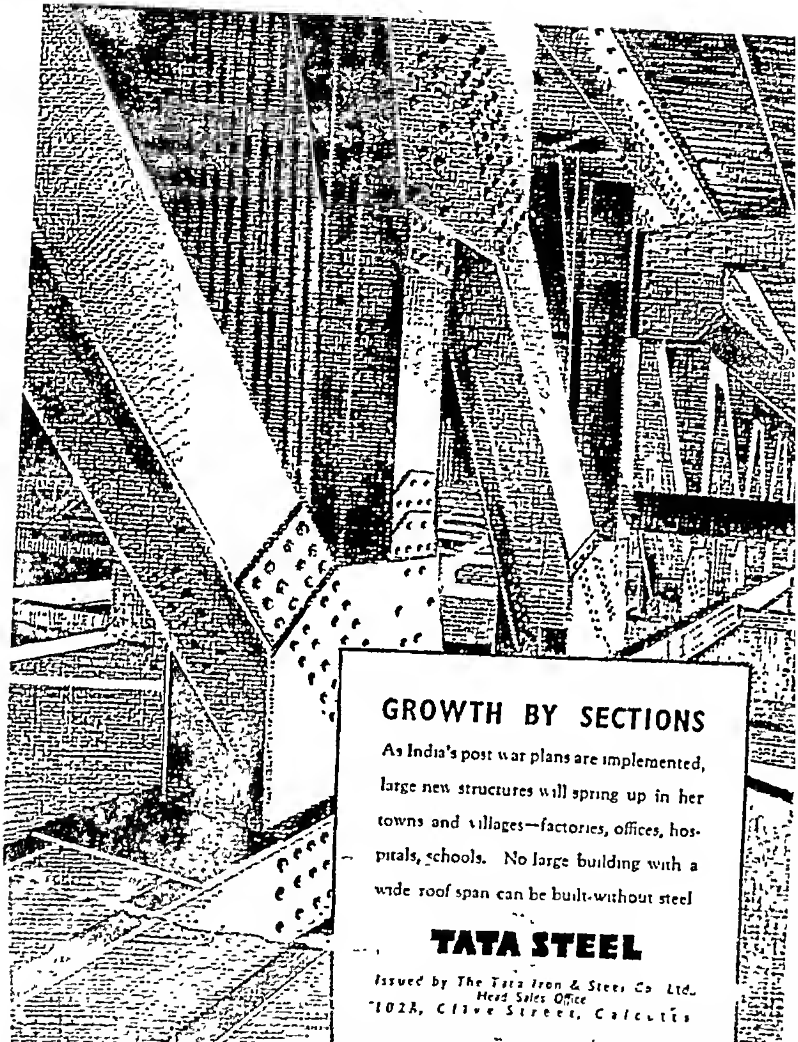
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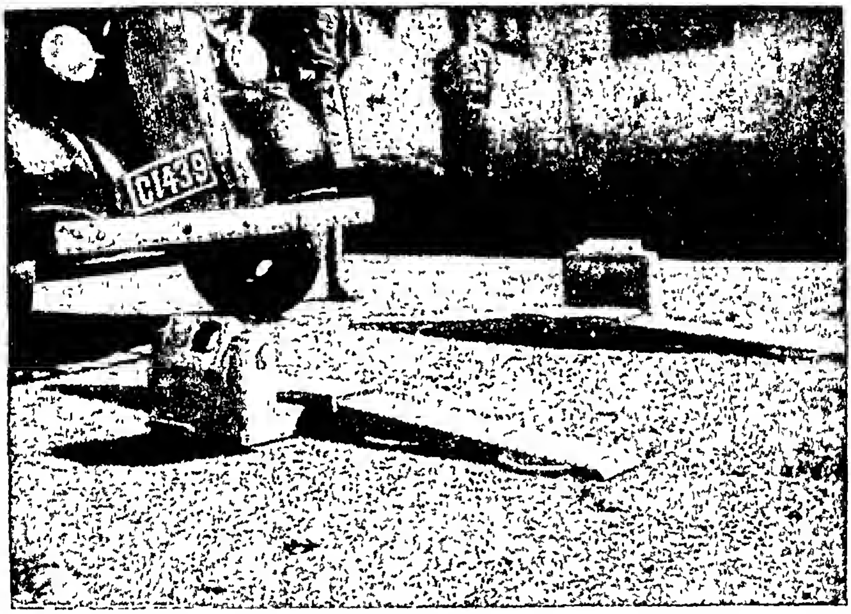

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The Indian Roads Congress as a body does not hold itself responsible for statements made, or for opinions expressed, in the Papers or discussions in *its proceedings.*

VESUGAR, Esq., I. S. E.,
President 1944-45

CONTENTS

The Council will be grateful for any information members can give regarding the present addresses of the members named below. Communications sent to them to the addresses registered in the Indian Roads Congress office have been received back undelivered:—

Name:	Last address registered in the office.
Radha Krishan, Esquire,	S.D.O., P.W. Dept., Lyallpore.
Korni, Dr. M.A.,	2, Bishop Lefroy Road, Calcutta.
Sri Ram, Esquire,	Chartered Engineer, 10, The Mall, Lahore
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Biswa, N., Esquire,	Assistant Engineer, Defence, P.O. Baripada.
Mahadav, T.K., Esquire,	Assistant Engineer, Municipal Corporation, Karachi.
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Stevens, Brig. A.E.,	Commanding Royal Engineer, Meerut District, Headquarters, Dehra Dun.
[illegible]tia, S.S., Esquire,	Superintending Engineer, P.W.D., Hyderabad (Deccan).

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Meares, Brig. C. D. N.,	C/o A.P.S. Nairobi, Kenya, (South Africa).

BUSINESS NOTICES AND ANNOUNCEMENTS

1. REVISED RATES OF SUBSCRIPTION WITH EFFECT FROM 1-10-1945.

At the Madras Session of the Indian Roads Congress held in February 1945, the rates of yearly subscription of Members were revised by the Council, as under. (Printed on pages 29-30 of Volume IX—Part 3).

	Rs.
Ordinary Members	20/-
Associate Members	120/-

Provided that a rebate of Rs. 5/- in the case of Ordinary Members and Rs. 20/- in the case of Associate Members, may be claimed if the subscriptions are paid within three months of the due date.

The effect of this revision is that the rate of subscription is uniform for all Ordinary Members irrespective of the pay drawn. Attention of all members is invited to the provision made for a rebate in the subscription if paid within three months from 1st October of the year. Members are specially requested to arrange payment by Bank orders.

Attention is also drawn to the new rules for compounding future annual subscriptions. These are printed on page 30 of Volume IX—Part 3 of February 1945.

2. MEDALS AND PRIZES

The following Medals are available for award:—

I. The Mitchell Medal: This is a bronze medal to be awarded annually for exceptionally good papers contributed to the Indian Roads Congress in any year. This has been instituted to perpetuate Sir Kenneth Mitchell's connexion with the Indian Roads Congress in particular and Indian Road Development in general.

II. The Indian Roads Congress Prize Essay Medal: This is also a bronze medal to be awarded annually for the best essay contributed by Members on any one of a panel of subjects selected by the Council from time to time.

The subjects selected by the Council for the year 1944-45 are:—

(1) Road mindedness—How to create a widespread public demand for more and better roads in India.

(2) Rural Roads and their Economics.

(3) Economics of Road maintenance.

(4) Cycle tracks and pedestrian pavements.

The Council has reserved the right to award more than one medal of either class in any one year or to withhold the award of any medal in any year without assigning any reason.

Special Prize Essay: A prize of Rs. 250/- is available for competition. This prize was offered at the Council meeting held on 7th October 1943 at Gwalior by Sir Kenneth Mitchell and Mr. Nur Mohd. Chinoy jointly for the best essay on "Post-war goods and passenger road transport and its economics". As no essay of sufficient merit was received in 1943-44, the Council decided with the approval of the donors to keep the competition open.

RULES AND REGULATIONS FOR PRIZE ESSAYS

(1) No essay shall exceed 6000 words in length.

(2) The essays received will be examined by a Committee appointed by the Council. The Committee shall decide whether any essay is admissible for the competition and to whom the award, if any, shall be made. The decision of the Committee shall be final. The Council shall have the right to withhold the prize if the contributions are not of sufficient merit.

(3) The last date for receipt of essays is 31st December 1945.

The following instructions are circulated for the guidance of authors of essays and papers:—

(i) Typing should be on one side of good stout paper of foolscap size, double spacing being used, with ample margin (not less than 2 inches) on the left-hand side.

(ii) The author's full name, designation and correct postal address should be given below the title of the paper.

(iii) As regards illustrations, these fall into 2 classes. *viz.*,—

(a) Line drawings.

(b) Half-tones.

Line drawings should be made in *black Indian Ink on superior white drawing paper or tracing cloth.* The size

of drawings should be as small as possible, compatible with legibility. Blue prints are of no use for reproduction, and black line prints are also unsatisfactory.

In large drawings, printing should be bold and lines should be clear and sufficiently heavy to allow for the reproduction of the drawing photographically. Angles must be neatly finished. Coloured inks must not be used.

Drawings should be of the size $6\frac{1}{2}$ in. by 4 in. or multiples thereof.

Scales for line-drawings should be drawn on the body of the drawings as a part thereof, to admit of reduction (or enlargements) of drawings without altering the correct relation of the scale to the drawing. Mere mention of the scale thus: "Scale 10 feet = 1 inch" should be avoided as this would be incorrect when the drawing is reduced photographically.

"Half-tones" are ordinary photographs and it is necessary to see that the prints are clear, slightly over-printed and, preferably, glazed. Photographs which are dim or out of focus do not come out distinctly in reproduction and make a bad "half-tone." The size of photographs should be from quarter plate to full plate. Negatives should accompany the photographs whenever possible, and will, if desired, be returned when done with. Captions should be written on the back of prints in soft pencil.

(iv) Members are particularly requested to use the units of weight measure, and cost standardized by the Congress (*vide* page 176 of Proceedings of the II Indian Roads Congress) and in papers describing road works to give the information required by the form of record drawn up by the Congress (*vide* page 184-185 of the Proceedings of the II Indian Roads Congress).

(v) Mathematical formulae should be drawn carefully by hand and not set out with the typewriter.

(vi) The use of abbreviations should be avoided. For example $6'—2'' \times 3'—3''$ should be written as 6 feet 2 inches by 3 feet 3 inches. Similarly, 225°C should be written as 225 degrees centigrade, and so on.

(vii) Only those words and phrases which are to be printed in italics should be underlined.

(viii) Sources of Quotations appearing in the Papers should be acknowledged.

(N.B.— All Contributions should be drafted in the third person).

3. PROCEDURE ON CONTRIBUTION OF TECHNICAL PAPERS

Our procedure in the past has been to invite Members to contribute Papers for discussion at the Indian Roads Congress meetings, a few months before the holding of the General Sessions. On receipt, the accepted Papers were circulated in advance to Members for prior study, a month or so before the date fixed for discussion. This procedure resulted in the receipt of a large number of Papers at one time and editing and printing had often to be done very hurriedly. Also Members often found that one month did not give them sufficient time to study a large number of Papers before the discussion at the Congress sessions.

2. It has therefore been decided by the Council that in future Members should be invited to contribute technical Papers to the Secretary throughout the year, as and when they are ready, and that the accepted Papers should be published in the Journals of the Society which, it is hoped, will be issued quarterly in future.

3. The Council considers that this will give Members more time to study the Papers and will facilitate editing and printing. A record of the discussion and the comments received by correspondence will be published with the Author's replies in the Journal issued after the General Session.

4. A beginning has been made by publishing the Ninth Proceedings in four parts. The first part of Volume Ten will, it is hoped, be issued in November 1945. It will contain Papers for discussion at the Tenth General Session if sufficient Papers are received in time.

5. It will be realized that it will only be possible to give effect to this new scheme if Members are willing to co-operate, and the Council appeals to them to contribute Papers for discussion throughout the year at their convenience.

6. The Standing Rules for the guidance of contributing Papers, as now slightly amended, are re-printed below. It is requested that Members may read these rules and observe them when submitting Papers to the Congress.

CONTRIBUTION OF TECHNICAL PAPERS

Procedure to be followed and instructions to be observed

1. Members intending to contribute Papers to the Indian Roads Congress on any subject connected with Highway Engineering, are requested to send their contributions to the Secretary as and when these are ready, without waiting for a special invitation,

2. Final acceptance of the Paper rests with the Council. In order, however, to avoid disappointment through the Council having to reject Papers owing to an excessive number being written on any one subject, it is requested that any Member intending to write a Paper should intimate to the Secretary, the subject on which he wishes to write with a short synopsis of the proposed Paper. He will then be informed whether his offer can be accepted.

3. The Council has decided that Papers from non-members who are experts or who have specialized knowledge will be welcome and acceptance of the Paper will carry honorary membership for the Author for the year, provided there are good reasons that the contributor cannot join the Congress as an ordinary member.

4. The Council has expressed the opinion that Members, when choosing subjects for contributing Papers, should bear in mind the fact that there is often a great deal more to be learnt from failures than from successes.

5. The following instructions are circulated for the guidance of Authors of Papers :—

ALL CONTRIBUTIONS SHOULD BE DRAFTED IN THE THIRD PERSON

(i) Papers should be typed on one side of good stout paper of foolscap size, double spacing being used, and an ample margin (not less than 2 inches) should be left on the left-hand side.

(ii) The Author's full name, designation and correct postal address should be given below the title of the Paper.

(iii) As regards illustrations, these fall into 2 classes, viz.—

(a) Line drawings.

(b) Half-tones.

Line drawings should be made in black Indian Ink on superior white drawing paper or tracing cloth. The size of drawings should be as small as possible, compatible with legibility. Blue prints are of no use for reproduction, and black line prints are also unsatisfactory.

In large drawings, printing should be bold and lines should be clear and sufficiently heavy to allow for the reproduction

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(iv) Members contributing Papers on any bridgework actually carried out are requested to give inter alia the following details :—

(1) A site plan showing the road and river for two miles on either side of the bridge site;

(2) A dimensioned cross-section of the roadway;

(3) The loading on which the design is based ;

(4) The cost per square foot of the elevation area comprised by the formation level and the bottom of the foundations, and

(5) The ratio of the total cost of the substructure to the cost of those parts of the superstructure as are subject to variation with variation of span.

(v) Members are particularly requested to use the standard

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The Indian Construction Co.,
110 B, Mount Road, Madras.

82. Suri, Lal Chand, Esq.,
Director,
South India Construction Co.,
1/199, Mount Road, Madras.

DEATHS & RESIGNATIONS

The Council have received, with regret, intimation of the following deaths and resignations:—

I. DEATHS

1. Shivdasani, K.J., Esqr.,
Larkana (Sind).

II. RESIGNATIONS

1. Devdhar, V.S., Esq.,
Surveyor of Works,
M.E.S., Kamptee.
2. Wincklar, L.A.H., Esq.,
Chief Engineer (Retd).
Mysore.

JOURNAL OF
THE INDIAN ROADS CONGRESS

NO. —1 NINTH SESSION
DECEMBER, 1944.

CONTENTS

INDIAN ROADS CONGRESS

PAPER NO. IX - 98.
1944.

CALCULATION OF THE STRUCTURE OF ROADS

By Brigadier W.G. Lang-Anderson, O.B.E.,
Chief Engineer, G.R.E.F.

---

1. Ask a competent engineer the following questions:—
   (a) Why did you make the foundations of that building such and such a width and depth?
   (b) How did you arrive at the depth and bed width of this canal?
   (c) Why is the main line on your water supply system 6 inches diameter?
   (d) Why did you install a 25 K. W. generating set in that power house?
   (e) Why are the girders of this bridge a certain size?

If he thinks you mean business, and are not merely a "Nosey Parker", he will give you a reasoned reply full of facts and formulae, with detailed calculations, probably ending with the words "which is safe".

2. Now, be a "Nosey Parker", and ask the engineer one more question.

> Why did you build the road from A to Z to a specification of 6 inches Soling with $4\frac{1}{2}$ inches of metal on top?

You will get reasons, supported by some general facts, but it is very unlikely that you will get any mathematical calculations nor a claim that the specification has been proved to be safe. This is not because the engineer has been careless but because road construction is largely treated as a "practical" trade the specifications of which are based on previous experience and rule of thumb methods.

3. The object of this paper, therefore, is to show that road construction, while not comparable to the mathematical exactitude of say steel work design, is nevertheless susceptible to theoretical calculation which should result in construction that is more

economical in all senses. It has not been possible to write an elaborate thesis but if the following brief paragraphs provoke thought, discussion, and criticism, they will have served their purpose.

4. The materials of road construction can be divided into three main classifications:—

(a) *Rigid materials* such as concrete, water-bound macadam, timber, and in some special cases, steel.

(b) *Plastic materials* such as tar or bitumen mixes of various types, and rubber.

(c) *Loose materials* such as earth, sand, and gravel.

5. The basic effect of traffic on these materials is to cause wear and eventual destruction through the exertion of pressure. The effect is accentuated by friction (which is caused by pressure), by impact (which merely increases pressure), and by suction (which is negative pressure).

6. *Rigid materials* absorb the pressure by their internal elasticity, distortion of form being slight, and they return to their original shape after the pressure is removed.

7. *Plastic materials* absorb the pressure by distorting until the pressure is distributed at an intensity equal to the resistance that the materials can offer. The materials are slightly distorted and may remain so until pressure exerted at an adjacent spot squeezes them back to about their original position.

8. *Loose materials* get displaced downwards and sideways until the particles interlock and compact to form a cone of resistance equal to the pressure exerted. The distortion is considerable and there is no tendency to return to original form.

9. Pressure, combined with other factors, affects not only the top surface of the road but also the material in the body of the road, as the pressure is transmitted through the material at an intensity decreasing with the depth. The recurring application and release of pressure must therefore in time break down the substructure. It is for this reason that, however well or frequently a water-bound macadam road is surfaced with tar and hard chippings to prevent surface wear, nevertheless after a number of years it will be necessary to scarify the metalling, add some fresh metal, and apply a new surface.

10. If a load of P is imposed on the surface of a road so as to cover uniformly a circle of r inches radius, then the intensity of pressure,

$$p=\frac{P}{\pi r^2} \qquad \text{(i)}$$

With homogeneous materials pressure is distributed downwards through the body of the road diverging at 45° from the vertical on all sides. Thus at a depth *h* inches below the surface the intensity of pressure is

$$p=\frac{P}{\pi\,(h+r)^2} \qquad \text{(ii)}$$

11. If at any horizontal section through the body of the road, the intensity of pressure is greater than the safe crushing load of the material at that section, then, the road will fail.

12. Likewise, if the surface of a road has not been consolidated by roller to an intensity of pressure greater than will be imposed by the traffic, then the road surface will fail. Exceptions to this are types of road surfaces such as concrete, or tar premix, which by the chemical action of setting or hardening obtain a greater hardness than is produced by the physical action of rolling.

13. The table below gives the intensity of pressure in lbs. per sq. in. at varying depths for different *radii* due to a load of one ton at the surface, by using formula (ii) above.

TABLE

Radius of contact surface in inches. r	Area of contact in sq. inches. $a=\pi r^2$	Intensity of Pressure in lbs. per sq. in. at depth *h* (inches) below the surface due to a load of 1 ton at the surface.							
		0 i.e. at surface.	½	1	2	3	4	5	6
0·5	0·79	2852	713	317	114	58	35	23	17
0·75	1·77	1290	456	233	94	51	31	21	16
1·0	3·14	713	317	178	78	45	29	19	15
1·5	7·11	317	178	114	58	35	23	17	13
2·0	12·57	178	114	78	45	29	19	15	11
2·5	19·60	114	78	58	35	23	17	13	10
3·0	28·30	78	58	45	29	19	15	11	9
4·0	50·20	45	35	29	19	15	11	9	7

14. The above table illustrates a number of interesting points.

20. As the road may be subjected to heavy bullock cart traffic the design worked out must be checked for this load.

The cart wheel may impose a load of 2240 lbs. on a rectangle 1. 3/4 inches × 1 inch. The $1\frac{1}{4}$ ins. thick premix will distribute this load over an area of 4.25 by 3.5 or 14.875 sq. inches, giving an intensity of pressure on the surface of the brickwork of 152 lbs. per sq. in. which is safe. But if the bullock cart traffic is likely to be intense it would be advisable to increase the thickness of the premix to $1\frac{1}{2}$ inches.

The whole load may be transmitted to one brick in the upper layer which again transmits it to 4 bricks in the lower layer. Thus the load is spread on an earth formation area of $4 \times 9 \times 4{\cdot}5 = 162$ sq. in. which gives a safe intensity of pressure of 14 lbs. per sq. in.

21. It is evident, therefore, that for class 12 loads, a brick road must consist of 2 layers of good quality bricks carefully bonded and covered with a premix carpet $1\frac{1}{4}$ in. thick. Anything less than this specification will fail in time. If the traffic is very light in volume, the failure may not take place for a few years thereby giving the wrong impression that the lesser specification adopted is satisfactory.

22. This has been proved recently in East India where many miles of road built of bricks only, with no surfacing, lasted for several years under the normal light civilian traffic. These roads have broken up irreparably in three or four months when subjected to intense traffic not greater than class 12 and almost entirely running on pneumatic tyres.

PAPER NO. IX–99
1944

"Adhesion of Bituminous Binders to stone metals and the use of Slaked lime for the Treatment of Wet Aggregates"

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INTRODUCTION

The construction of Road Surfaces calls for careful selection of both materials and specifications after consideration of local conditions and traffic demands.

In the case of stone metal for waterbound macadam, wherever a choice of aggregate is possible, the Road Engineer will naturally select the stone metal yielding the best average results from such physical tests as the Abrasion, Attrition, Impact and Crushing Tests. In the case of stone metal to be employed for bituminous treatment, the adhesion exhibited between the stone metal and the binder to be utilised should also be given consideration before a final selection is made.

Various types of stone metals possess very different properties in respect of their strength of adhesion to binders. It is important, except in very dry climates, that a stone metal coated with bituminous binder should not subsequently evince a preference for water resulting in a replacement or stripping of the binder by water, for, should this occur in a road surface subjected to continuously damp conditions, a serious disintegration of that surface will ensue under the impact of traffic.

It is the object of this paper to discuss :—

(i) the various factors controlling adhesion between stone-metal and bituminous binders, as at present understood,

(ii) the tests employed to detect strength of adhesion, and

(iii) the means by which such adhesion can be improved.

PART 1

Factors Controlling Adhesion

Mechanism of Adhesion. The mechanism of adhesion between stone metal and binders is as yet not completely understood, although certain general principles do emerge from the evidence at our disposal. The majority of road stones do not normally exhibit strong adhesion towards bituminous binders in the presence of water, but

show a preferential affinity for the latter and are in consequence termed "hydrophilic". Other stones however do exist, which show a preferential affinity for binders and these are termed "hydrophobic."

Generally speaking "hydrophobic" stone metals are basic in character and include limestone, slag, and certain types of basalt.

Conversely the hydrophilic stone metals are usually acidic in type comprising granites and quartzites and are the more commonly encountered in actual practice.

A proper appreciation of the mechanism of adhesion can only be obtained by a detailed consideration of the physical properties of both the Road metals and Road binders.

Physical Nature of Road Stones. The exact nature of most road stones is extremely varied from a mineralogical point of view and many rocks passing under the same geological or petrological name or classification are very different as regards their mineralogical constitution. For this reason it must be realised that there can be no simple geological classification of road stones in respect of adhesive properties. Each separate source of stone metal therefore deserves individual examination and test even if the parent rock has been classified, particularly if it is composed of mixed crystals and conglomerates.

It is claimed by Dr. Knight[1] and others that the surface texture or rugosity and the grain size of a stone metal surface, as disclosed under the microscope, is of greater significance in determining adhesion than its mineral character. However, the classification of stone metal in this way is not a simple matter, and cannot be carried out in the ordinary testing laboratory. According to Dr. Knight micrographic projections giving the surface profile a magnification of 50 times, enable a reliable estimate of adhesive properties of minerals to be formed on a comparative basis.

The influence of surface texture on adhesion problems is undoubtedly of considerable importance and it has been shown by Lee,[2] who has carried out a series of tests with binders on certain mineral substances in the coarse and in the highly polished state, that differences in the adhesive properties recorded on the coarse minerals tended to disappear when the same tests were applied to highly polished surfaces of the same minerals.

Physical Nature of Binders. The physical nature of bitumen and tars has been the subject of a number of papers by Nellensteyn

and his collaborators. Both types of binders are essentially colloidal suspensions of carbonaceous particles, or 'micelles', in an oily medium or continuous phase. In the case of Road Tar the solid particles of the disperse phase vary considerably in size from macrons to microns and ultramicrons. The continuous phase is tar oil or creosote. In the case of Asphaltic Bitumen the disperse phase consists solely of ultramicrons and the continuous phase is a heavy petroleum oil. The solid particles or *micelles* consist, according to Nellensteyn, of a central core of carbon surrounded by protective bodies produced during distillation, see Figure I. The ratio of volume of dispersed micelles to that of the continuous oil phase will determine the thickness or viscosity of the binder.

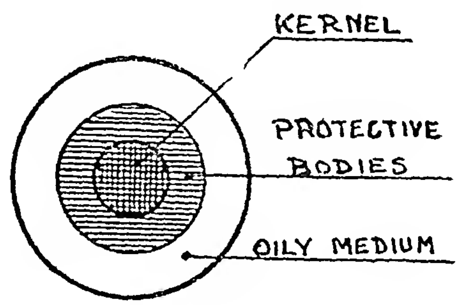

Fig. 1.

The stability of a bituminous system can be upset by the addition of certain organic solvents which can break down the layer of protective bodies and flocculate the *micelles* and destroy the colloidal suspension of the disperse phase.

Thus Carbon Bisulphide and Benzene will flocculate the "free carbon" or carbonaceous micelles in Road Tar although these solvents do not flocculate the micelles in Bitumen.

The latter are however flocculated in varying degrees (i) by Petroleum Naphtha yielding Asphaltenes (ii) by Carbon Tetrachloride yielding Carbenes. The components dissolving in the solvent are termed *Malthenes* and consist of Asphaltic Resins and Petrolenes or oily constituents.

Nellensteyn has attempted to correlate the surface Tensions of the flocculating solvents with those of the binders themselves, but his theory of relationship does not seem tenable in the light of the latest results of other observers. The property of Surface Tension is of such importance in the study of adhesion problems, however, that it will not be out of place to consider here those aspects which have a direct bearing on this problem, before proceeding further.

Interfacial Tension—Surface Tension—Adhesion Tension.

At the interface of two non-miscible liquids in contact, an interfacial tension exists which tends to reduce the area of contact between the two liquids to a minimum.

Energy must be expended to increase the area of contact of two liquids and the work required to increase the contact area by 1 sq. cm. is called the *Interfacial Tension* (*S*) between the liquids in question, and may be expressed thus:—

$\delta w = S.\ \delta a$ where w is work required to increase the contact area by "a".

Hence, Interfacial Tension is expressed as Ergs per sq. cm. or, more simply, as dynes per cm.

When one liquid is replaced by a gas it is found that the nature of the gas has very little effect on the interfacial tension for a given liquid and the term *Surface Tension* is applied to denote the interfacial tension of that liquid in contact with air or any gaseous phase.

The surface tensions of various liquids are given below for comparison:—

Water	. 72	dynes per cm.	at 25°C
Glycerol	.. 63	,, ,,	,, 17°C
Nitrobenzene	.. 42·5	,, ,,	,, 26·°C
Pyridine	.. 35·5	,, ,,	,, 20°C
Carbon Bisulphide	.. 31·0	,, ,,	,, 20°C
Benzene ..	.. 28·8	,, ,,	,, 20°C
Carbon Tetrachloride	25·7	,, ,,	,, 20°C
Alcohol	.. 21·0	,, ,,	,, 25°C
Petroleum Naphtha	.. 17.4	,, ,,	,, 20°C

The presence of solids in solution normally causes a rise in the Surface Tension of the solvent e.g., in the case of water the Surface Tension may be increased to between 80 & 90 dynes per cm. by the presence of salts in solution.

It is seen that the Surface Tension of water is high in comparison with those of most organic solvents, which fall between 17 and 45 dynes per cm.

The presence of soaps in solution in water, however, have a very striking effect on the Surface Tension which is reduced to well within the range of those of the organic solvents. Thus the Surface Tension of 0.25 per cent. aqueous soap solution is 23.3 dynes per cm. at 20°C.

In comparison with liquids, the Surface Tensions of metals in the liquid or molten state assume very high values e.g.:—

Mercury	520	dynes per cm.
Silver	1000	,, ,,
Platinum	2000	,, ,,

Interfacial and Surface Tensions are derived from inter-molecular attractions and in the case of non-miscible liquids the force of attractions between molecules of the same chemical constitution for each other on either side of the interface is greater than the force of attraction between molecules of different chemical constitution on opposite sides of the interface.

According to *Antonow's Rule* the interfacial tension between two non-miscible liquids is numerically equal to the difference between their individual surface tensions.

A method of determining Interfacial or Surface Tensions of liquids has recently been standardised.

Details are to be found in "Standard Methods for Testing Petroleum & its Products" 1944, p. 348.

This method proposes the adoption of the *du Noüy Torsion Balance* in conjunction with a thin rectangular glass plate.

The apparatus is sketched in Figure 2 and consists essentially of a taut wire W whose degree of torsion can be controlled by an adjustable screw at one end and a vernier torsion dial A at the other. A beam B hooked at one end is fixed rigidly to the wire and at right angles to it, and operates between adjustable stops at C. From the beam hook is suspended the rectangular glass plate, shown separately with dimensions in figure 2A, which is immersed in the liquid for test contained in a glass dish set on the horizontal platform D, the height of which can be adjusted by the screw E.

The instrument is adjusted so that the lower edge of the glass plate just touches the surface of the liquid under test. Torsion on the wire is then applied at the dial until the glass plate just disengages and the beam starts to rise.

The surface tension of the liquid,

Where R = reading on dial in degrees
P = perimeter of the lower edge of the glass plate in ems.
D = pull in dynes per degree on the dial (determined by calibration with known weights)

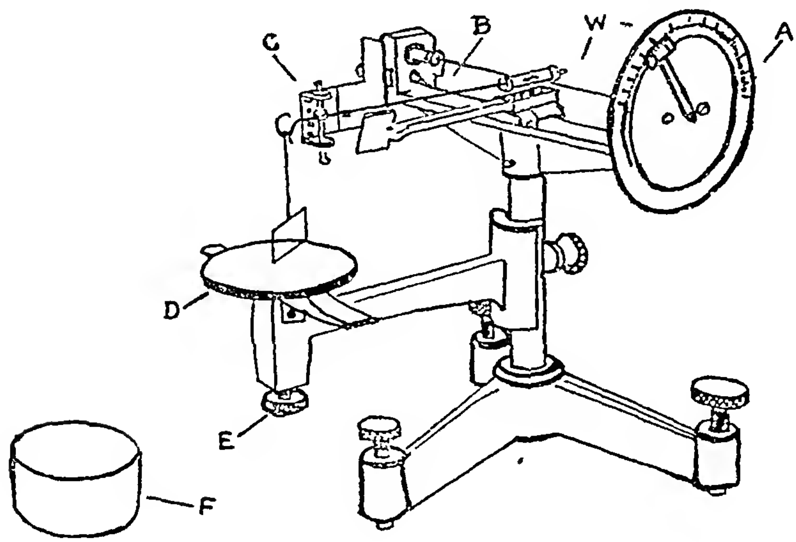

Fig. 2

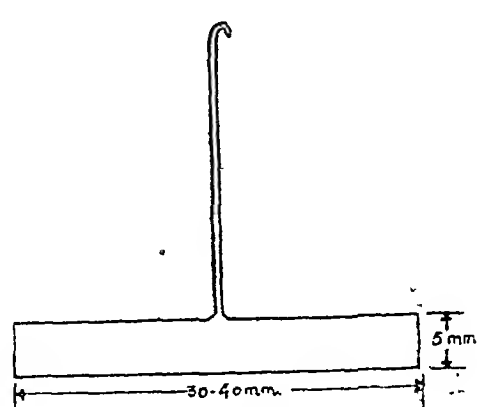

FIG 2A.

Interfacial Tensions between two non-miscible liquids can be determined in an identical manner by measuring the torsion necessary to disengage the plate from the interface of the liquids.

Surface Energy & Surface Tension.

It will be realised that Surface Tension represents a storage of potential energy which is capable of performing work. This energy will be proportional to the surface area over which the surface tension exists.

The surface energy of a system will always attempt to adjust itself so as to reach the lowest possible level, and hence the tendency of liquids to attain minimum surface area in the form of spherical drops.

In the case of a drop of non-wetting liquid resting on a solid, distortion from the spherical shape takes place as energy is expended by gravity against the surface tension of the liquid.

In the case of rigid surfaces a lower level of potential energy can be reached at the solid surface if a liquid wets the surface producing a lower interfacial tension than the normal surface tension of the solid in air. This will be found to occur with liquids of low surface tension, or with solutions of electrolytes irrespective of their surface tensions.

These effects are discussed later in connection with Adhesion Tests.

Wetting Properties of Liquids on Solids. When a liquid comes into contact with a solid surface it will exhibit a certain tendency to spread itself over and wet the surface. This ability to wet the surface will be dependent on the surface tension of the liquid, the solid and the interfacial tension between the liquid and solid.

Poor wetting ability will be instanced by drop formation on the part of the liquid e.g. the behaviour of mercury on any non-amalgamating surface and that of water on waxed or rubberised surfaces and on the proverbial duck's back.

Good wetting ability results in the rapid formation of a complete film of the liquid over the solid surface, the liquid thereby displacing air from the solid surface.

If we consider a drop of partially wetting liquid on a solid surface we find the following forces in equilibrium :—

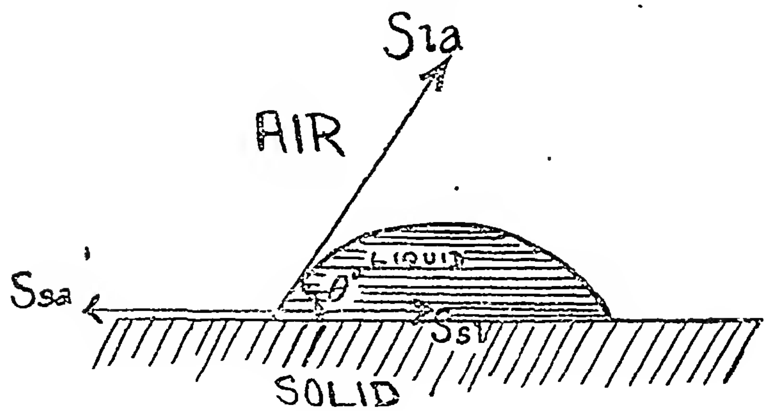

Fig 3.

S_{la} = surface tension of the liquid in air
S_{sl} = interfacial tension between the liquid and solid
S_{sa} = surface tension of the solid in air.

If the drop, when in a state of equilibrium, subtends an angle θ with the solid-liquid interface, then

$$S_{sa} - S_{sl} = S_{la} \text{ Cos}\theta = \text{Adhesion Tension } (A)$$

This term, *Adhesion Tension*, attributable to Freundlich[3] which is the product of the Surface Tension of the liquid and the cosine of the angle of contact, is a measure of the adhesion between liquid and solid.

Adhesion Tension is favoured by a lowering of the surface and interfacial tension of the liquid resulting in a decrease in the contact angle until it assumes a value of Zero and $\text{Cos}\theta = 1$

Then $S_{sa} = S_{la} + S_{sl}$ and complete wetting takes place.

Conversely, an increase in surface and interfacial tensions of the liquid will result in an increase in contact angle until a value of 90^0 is reached when $S_{sa} - S_{sl} = 0$ and the adhesion tension assumes Zero value.

Observations of contact angles of partially wetting liquids on smooth solid surfaces have been utilised to determine values of adhesion tensions and surface tensions of various minerals.

According to Nellensteyn[4] $S_{sa} = \frac{1}{2}(S_{la} - A)$

Loman and Zwikker[5] report the following values for surface tensions of solid surfaces (S_{sa}) by measurement of contact angles of mercury and water drops :—

Quartz	130 — 135 dynes per cm.
Porphyry	55 ,, ,, ,,
Granite	55 ,, ,, ,,
Grey Marble	50 ,, ,, ,,
Hard Limestone	33 ,, ,, ,,

As these values of solid surface tensions are well in excess of the surface tensions of bituminous binders, it follows that the latter will be capable of completely wetting these mineral surfaces.

Let us now consider the system if air is replaced by water and the adhesion tension of the water-solid system is competing with the adhesion tension of the solid-liquid system for possession of the solid surface.

If the water succeeds in partially displacing a drop of liquid binder from a solid surface the following state of affairs is reached :

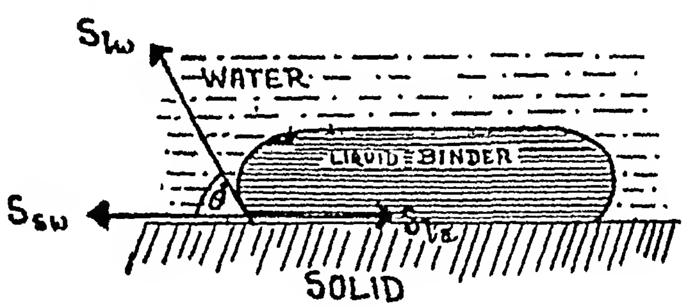

Fig. 4

The adhesion tensions of the two systems may be expressed thus :—

$$A_{sl} = S_{sa} - S_{sl}, \text{ for the solid-liquid (binder) system.}$$
$$A_{sw} = S_{sa} - S_{sw}, \text{ for the solid water system.}$$

The resultant Adhesion Tension,

$$A_{sw} - A_{sl} = S_{sl} - S_{sw}$$
$$= - S_{wl} \, Cos \, \theta.$$

where θ = contact angle between the liquid binder and water phase.

Observations on contact angles in systems of this type have

been carried out with horizontal miscroscopes at the Road Research Laboratory, Harmondsworth, and interfacial tensions and contact angles recorded photographically for a variety of liquid binders in contact with water on polished glass plates.

It will be noted from equation—

$$S_{sl} - S_{sw} = S_{w} \ Cos\ \theta.$$

that the contact angle is independent of the surface tension of the Solid S_{sa} and this is borne out by experimental results which disclose that contact angles are dependent on the degree of polish rather than the chemical nature of the solid.

The contact angle is however dependent on the difference between the interfacial tensions of the solid-binder and solid-interfaces. The larger the difference the greater will be the tendency of the water to strip off the binder, and the smaller the value the greater the ability of the binder to retain its adhesion. A lowering of the interfacial tension of the solid-water interface will promote stripping of the binder and a lowering of the solid-binder interfacial tension will promote binder adhesion.

Lee (loc. cit) has reported a series of investigations into the wetting properties in the presence of water for a series of Coal Tars of high and low temperature type over a wide range of viscosities by the methods referred to above. For high temperature Tars, corresponding to normal Road Tars, the interfacial tension S_{wl} varied from 20 dynes per cm. for a Road Tar No. 1 to 16 dynes per cm. for a high viscosity Road Tar. The corresponding values for $\cos\theta$ were 0·62 and 0·94 and for $S_{wl}\cos\theta$, 12·4 and 15·0 dynes per cm. respectively.

The resultant adhesion tension $S_{wl}\cos\theta$, as thus reported, is a measure of force exerted by the water to displace the binder from the solid surface ana consequently the lower the value of this resultant adesion tension, the better the wetting power of the binder in the presence of water.

In the case of creosote, the values for $S_{wl}\cos\theta$ approximate fairly closely to those for Road Tar No. 1, so we can state that in the lower viscosity Road Tars the wetting properties correspond to those of the oily continuous phase, but for thicker tars the higher concentration of the disperse phase brings about some diminution in the wetting power.

The above determinations were carried out on plate glass but when polished surfaces of granite, whinstone, marble and

limestone were substituted little difference in the wetting power of binder was evidenced on these various minerals.

Adhesion of Binders to Wet Aggregates

The main factors which control the adhesion of binders to wet mineral aggregate in practice are:—

(1) Resultant adhesion tension of the binder to the wet aggregate.
(2) Surface texture of the mineral aggregate.
(3) Viscosity of binder.

(1) **The Resultant Adhesion Tension** is dependent on—

(a) Interfacial Tension at the solid/binder interface.
(b) Interfacial Tension at the solid/water interface.

These Interfacial Tensions are influenced by the surface tensions of the respective liquids and reflect the degree of attraction between solid and liquid phases in contact.

Wetting of the solid surface will be favoured by:—

(1) low surface tension of the liquid phase,
(2) electrolytic attraction at the solid-liquid interface.

(2) Surface Texture

A rough and porous texture will favour resistance to displacement from a solid surface of one liquid by another, as the more rugous the surface the more energy must be expended per unit area by the displacing liquid in taking possession.

Hence, if a binder has already coated a rugous surface, displacement by water will prove more difficult than in the case of a smooth solid surface of the same material.

Conversely, it will be found more difficult for a binder to coat a damp rugous surface than would be the case if the same surface were polished and smooth.

(3) Viscosity of Binder

The more viscous a binder the more capable it is of resistance to displacement by water for the reason that greater energy is required to cause the binder to flow from the surface.

Unduly high viscosity, however, is not likely to favour initial wetting of the solid surface as it is usually found that for a

given binder an increase in viscosity results in an increase in surface tension.

The ideal binder should therefore display a low viscosity at the time of application but should set up to a high viscosity in as short a time as possible after coating of the stone metal is completed in order to resist subsequent displacement.

PART II

Adhesion Tests for Binders

It has been attempted by a number of observers to assess the sum total of the various factors controlling adhesion as described above. by evolving a satisfactory accelerated test which will disclose the probable behaviour of binders applied to stone metal road aggregates under conditions actually obtaining in practice.

The tests which have attracted most practical attention are those of Nicholson[7] (based on researches by Bartell) and Riedel and Weber[8].

A test similar to that of Nicholson's has been described by Hughes[9]. An official adhesion test sponsored by the Road Research Laboratory, Harmondsworth has been promised[10], but has not yet, so far as is known, made its appearance.

Riedel and Weber, who have published a very thorough symposium on adhesion entitled "Ueber die Haftfestigkeit Bituminoser Bindemittel an Gesteinen", have evolved a test which has been described in the official German Specification for Road Binders, DIN 1995 published in 1934.

Nicholson's Test.

This is carried out in two parts:—

1. Water Test.—Coat the stone metal with binder and agitate with water for 1 hour at various temperatures. The degree of stripping of the binder indicates its adhesive power. the severity of the test increasing with temperature.

2. Solvent Test.—Coat the stone metal with binder and flux with various quantities of a selected solvent (benzol) and agitate with water at ordinary temperatures for 1 hour.

The degree of adhesion is measured by the quantity of solvent necessary to bring about stripping of the binder.

The above test is not, in the author's opinion, to be recommended as a means of determining adhesive strength.

The scope of the "water test" is very limited, and merely differentiates between 'poor' and 'not so poor' adhesion. The difference in wetting ability between hot and cold water is not marked and a corresponding difference will also exist in the case of binders in the hot and cold state.

The heating of the stone metal-binder mixtures in water is more likely to cause stripping through a reduction in the viscosity of the binder than on account of the increased relative wetting ability of the water.

So far as the "solvent test" is concerned, this does not appear to be based on sound principles. The effect of the solvent will be firstly to reduce the viscosity of the binder, and then possibly to cause a breakdown in the physical structure of the binder. As this action does not take place under actual conditions the test is not likely to lead to results of practical significance.

Riedel and Weber Test

The test is carried out according to the following procedure:—

The Road metal to be tested should be of particle size K2 (i.e. 2-6 mm. or 25-80 mesh) and is intimately mixed with the binder in the proportions of 71 per cent. stone and 29 per cent. binder by volume.

About 0·5 gm. is boiled for one minute with water in a small beaker or test tube. If the binder strips off the stone, bad adhesion is indicated. If the stone withstands the preliminary test then further 0·5 gm. samples of the same mixture are boiled for the same time with 6 mls. of Sodium Carbonate solution of increasing strength until stripping takes place, the concentration of the solution which causes stripping being the measure of adhesion. The concentrations used are as follows:—

Concentration	Degree of Adhesion
O water	0
M/256 Na_2 Co_3	1
M/128 ,,	2
M/64 ,,	3
M/32 ,,	4
M/16 ,,	5
M/8 ,,	6
M/4 ,,	7
M/2 ,,	8
M ,,	9
No stripping	10

The molecular concentration solution (M) is prepared by dissolving 106 gms. of pure anhydrous Sodium Carbonate in one litre of distilled water. The other concentrations are prepared by suitable dilution with distilled water.

Before discussing the merits of this test it will be of considerable interest to trace the evolution of the test by the authors which resulted from a comprehensive series of investigations.

Firstly, they tested the stability of a number of stone metal-binder systems by boiling with water for one minute. This enabled them to classify such systems into two groups :—

(1) in which water displaced the binder and
(2) in which no displacement of binder took place.

It is claimed that boiling the mixtures in water merely accelerates the result and does not adversely affect the properties of the binder. The authors found that the nature of the binder had little or no effect on the classification of the stone metals i.e. stone metals showing good adhesion with tars showed, with few exceptions, good adhesion with Bitumens and vice versa. It was noted however in the case of Tars that in some instances full adhesive strength did not develop until some time had elapsed (say 2 to 3 months) after coating the stone metal with Tar.

Riedel and Weber's classification of stone metals is as follows:—

(1) Poor adhesion for binders ("hydrophilic" type).
Syenite
Granite
Porphyry
Quartz
Gravel

(2) Good adhesion for binders ("hydrophobic" type).
Sand
Greenstone
Limestone
Basalt
Graywacke
Slag

The authors stress the importance of not generalising on the performance of stone metals of any particular geological type, as they may vary considerably according to their source. It is important to submit every specimen to test.

In order to differentiate between the adhesive powers of the hydrophobic minerals, Riedel and Weber next replaced water in their boiling test by solutions of Sodium Oleate (soap) of varying concentrations upto 0.25 per cent. by weight. By virtue of the greatly reduced surface and interfacial tensions as compared with that of water these solutions are able to exert a much stronger stripping action on binders.

The maximum concentration of Sodium Oleate employed was 0.25 per cent. by weight as this corresponds to the minimum surface tension of 23.3 dynes per cm. at 20°C as compared with 72.8 dynes per cm. for pure water. Higher soap concentrations exhibit somewhat higher surface tensions.

Stone metal-binder mixtures were tested against the stripping action of a series of soap solutions, and the minimum concentrations at which stripping occurred after boiling 0.5 gm. of the mixtures wtih 6 mls. of the solutions for 1 minute were recorded. This enabled a classification of the hydrophobic stone metal-binder mixtures to be made in terms of adhesive strength or wetting power of the binders in each mixture.

As a result of this the general superiority of limestones and slags as regards adhesive strength was apparent but again the danger of generalising, so far as stone metal types are concerned, was strongly emphasised.

Riedel and Weber were also able to show by means of this test that, where displacement is brought about by surface tension, the proportion of binder to stone metal is immaterial.

On applying this test to selected stone metals coated with various film thicknesses of binder ($6\ \mu$ to $40\ \mu$) no difference in the adhesive strength could be attributed to the variation in film thickness.

The film thicknesses given above correspond to 4.0 per cent. and 30 per cent. by weight of binder approximately on the particular stone metals tested.

As regards the nature of the binder, the authors of this test found that the cause of good or bad adhesion is chiefly due to the varying characteristics of the stone metals rather than to the nature of the binders. In certain instances it was again found that Tars required an appreciable setting period to elapse before achieving full adhesion strength, particularly in the case of lower viscosity Tars.

Riedel and Weber also applied the foregoing tests in the cold to stone metal-oil mixtures, the oils tested being various mineral oils and anthracene oil. The results generally corresponded with those obtained with stone metal-binder mixtures and the conclusion to be drawn is that the wetting qualities of a given binder correspond closely with those of the continuous oily phase of the binder.

Riedel and Weber next turned their attention to the action of aqueous solutions of common inorganic chemical compounds, which by virtue of their dissociation into + and − ions (i.e. anions and cations) are termed electrolytes and are capable of transmitting electricity. Such compounds can be grouped as neutral, acid and alkaline. It was found that these solutions possessed very pronounced ability for replacing bituminous binders from stone metal surfaces, although as has been previously mentioned, the surface tensions of such solutions differ only slightly from that of pure water. Their ability to cause displacement of such binders is clearly derived from some property other than that of Surface Tension.

It has been reported in the Report of the Road Research Board[6] that displacement of Tar Films from stone metal surfaces varies according to Hydrogen Ion concentration or pH value. For slightly acid solution (pH_2 to pH_6), displacement is very slight and for neutral solutions (pH_6 to pH_8) more pronounced. For slightly alkaline solutions (pH_8 to pH_{10}), displacement is a maximum but for stronger alkaline solutions above pH_{10} it again diminishes in intensity.

Results obtained by Riedel and Weber with acidic and alkaline solutions, such as Caustic Soda, $\overset{+}{Na}\overset{-}{OH}$ and Hydrochloric Acid, $\overset{+}{H}\overset{-}{Cl}$, gave anomalous results and this can be attributed to the fact that these chemically active compounds often react chemically in various ways on the mineral surfaces or on the binders and thereby cause secondary effects which mark the true wetting qualities of their solutions.

For this reason it is satisfactory only to make observations on the behaviour of aqueous solutions of salts such as Sodium Chloride $\overset{+}{Na}\ \overset{-}{Cl}$ Sodium Carbonate ($\overset{++}{Na_2}\ \overset{=}{CO_3}$) and Sodium Sulphate ($\overset{++}{Na_2}\overset{=}{SO_4}$) which have no pronounced acidic or basic properties and do not affect the stone metal or binder chemically. Salts of this type do exist in natural soils and in consequence their

solutions may well, on occasions, come into contact with bituminous surfacings, thus giving this investigation a practical significance.

It was found that these solutions behave in a way very similar to that of the soap solutions already described and that the relative adhesive strengths of various stone metal-binder systems, as determined by displacement with soap solutions correspond closely to the values obtained if the latter are substituted by aqueous solutions of these inorganic salts.

The wetting ability of such salts was found to increase with the concentration and again with the valency of the anion (i.e. $\overset{+\,+}{Na_2}\,\overset{=}{SO_4}$ has greater wetting ability than $\overset{+}{Na}\,\overset{-}{Cl}$ but less than $\overset{+\,+\,+}{Na_3}\,\overset{\equiv}{PO_4}$).

The more concentrated solutions of these salts were found to have a greater wetting power than that of the soap solutions and could displace binder from certain binder-stone metal mixtures which were unaffected by the latter.

Furthermore, such solutions did not give rise to certain anomalous results noted in the case of soap solutions which were attributable to the alkaline nature of soap solutions.

One point of difference in the case of the stripping action of soap and saline solutions is that, while with the former the quantity of binder or the film thickness does not affect the results, in the case of the saline solutions binder displacement is found to be dependent on the film thickness. The thicker the binder film the more concentrated must the solution be in order to achieve displacement.

Hence, when employing saline solutions for determining adhesion strength it is important to standardise the quantity of binder employed in the test.

Messrs. Riedel and Weber as a result of their investigations standardised the use of Sodium Carbonate for the Adhesion Test as giving a wider range and more uniform results than the use of soap solution.

From the details of the test given on page 13 it will be seen that Adhesion between stone metals and binders can be classified thereby into ten degrees by employing solutions of different concentrations of Sodium Carbonate varying from molecular (i.e. 106 gms. per litre) down to nil.

In interpreting results reported for the Riedel and Weber Test for adhesive strengths it must be appreciated that the numbers corresponding to the increasing concentrations of the stripping solutions do not represent direct proportionality but a lower function, thus an adhesive strength of 6 (concentration of $\frac{M}{8}$) is twice (and not thrice) that of 2 (concentration $\frac{M}{128}$).

The wetting ability of electrolytic solution appears to be attributable to the effective lowering of the potential surface energy at the solid/solution interface.

It was stated on page 13 that when a liquid wets a solid surface in contact with air, a lowering of the surface energy occurs.

The more affinity that is exerted between the liquid and solid at the interface the greater will be the drop in the surface energy and the more stable the system will become. Hence liquids producing the lowest level of surface energy on a given solid surface will prove to have the lowest interfacial tension and the strongest adhesive properties.

Electrolytic solutions appear to be imbued with this ability to lower surface energy by virtue of the presence of positively charged anions (eg. $\overset{+}{Na}$) in solution, which exhibit an affinity for the molecules of the solid surface.

This method of reducing the interfacial tension is definitely more effective than that resulting from the lowering of surface tension alone, and this has led to the adoption of the Riedel and Weber Test in its present form employing aqueous Sodium Carbonate solutions in place of soap solutions.

This affinity at the interface is evident in the case of more stone road metals in contact with aqueous solutions and they are therefore classified as "Hydrophilic". In some cases however this affinity between electrolytes and the stone metal is less in evidence and the latter exhibits a preference for binders of chemically organic origin and the stone metals are consequently classified as "Hydrophobic".

Merits of the Riedel and Weber Test

The Riedel & Weber test, which admittedly gives results of much practical interest, has come in for criticism from certain

quarters, and the results obtained by this test should undoubtedly be interpreted cautiously.

Certain aspects of the test need detailed consideration :—

(1) **Particle Size.** The authors of the test state the size of particle selected (25-80 mesh) represents a good mean value, but in practice other workers have expressed the opinion that it is too small and is found to lead to very ambiguous results in the case of metals containing mixed varieties of coarse grained minerals, as has been pointed out by Dr. B. H. Knight (loc. cit).

When such minerals are reduced to the particle size stipulated the nature of the individual grains will vary (e.g. felspar & hornblend) and exhibit entirely different adhesive properties.

In order to obtain results more in keeping with practice it is evident a test of this nature should be made on an average size of stone metal chipping such as most commonly employed in actual road surfacing, i.e. from $\frac{1}{4}$in.-$\frac{3}{4}$ in. size.

Any variation in the surface crystalline structure of the mineral will not then adversely affect the test and a fair average result corresponding to the actual behaviour of the mineral in practice should be obtainable.

(2) **Detection of Stripping.** In the Riedel and Weber test it was not found possible to determine a definite alkaline concentration at which stripping or separation of the binder from the mineral could be said to be complete, after boiling for one minute. In the case of trap metals which, when damp, assume almost the same colour as the bituminous materials, it is very difficult to detect when separation has occurred particularly on the small size particles. Other observers[11] using the test on limestone and a variety of coal tars modified the test and took as the value of the adhesion the minimum concentration which caused turbidity of the solution after one minute's boiling. This method has been tried by the present writer but it was not found to be generally applicable.

(3) **Time of Exposure after Coating.** No details are given by Riedel and Weber as to what time should elapse between the coating of the mineral with the binder and the application of the boiling test, although they state elsewhere that in the case of Tars the adhesive strength with some stone-metals is very greatly increased if the coated particles are exposed for considerable period (e.g. six or twelve months) before applying the boiling test. Such changes do not occur with bitumens, and presumably can be attributed to the fact that whereas the setting of bitumen is brought about mainly by

cooling, in the case of Road Tars evaporation of the lower boiling Tar Oils must first occur to achieve full setting and this process takes place gradually over a period of time. The more viscous residual tar remaining becomes less easy to separate from the mineral surface than the tar as originally coated. It is not, of course, convenient in a routine test of this nature to allow long periods to elapse between the time of coating the mineral and applying the adhesion test, but a definite period of exposure should be allowed and in the case of Road Tars it has been found preferable to allow twenty-four hours between coating and testing to permit an initial set in binder film.

For these reasons the Riedel and Weber Test is not, in its original form, suitable for comparing the strength of adhesion of various binders for a given stone-metal. The test was intended originally to give comparative results of the adhesion between various types of stone-metal and road binders generally. To draw distinctions between the adhesion of different binders it is clearly essential to permit sufficient time to elapse after coating the stone metal specimens for the binders to set up fully, as occurs, in actual practice.

In studying the various results reported by Riedel and Weber, it should be borne in mind that German Road Tars, which are Anthracene (high boiling point) oil-pitch blends, differ in type from the usual Road Tars supplied under British Standard specifications.

It is presumably for this reason that they report the Surface Tensions of Road Tars at circa 40 dynes per cm. in contrast to Lee (loc. cit.) who in the case of British Road Tars reports Surface Tensions of approximately half this value.

Modifications of Riedel and Weber's Test.

The official German specification, DIN 1995, published in 1934 include a number of tests for determining the cohesive and adhesive properties of bituminous emulsions and cut-backs. The Riedel and Weber test is described therein but is not included in the actual specification tests to be applied.

Among the tests specified for cut-back bitumens one test (U 37) is designed to test the adhesion between binders and a selected stone metal, in the presence of water.

In this test 300 gms. of dust-free Basalt chips (¼ in.—⅛ in. size

approx.) or the stone metal selected for use, are warmed in an iron dish to 40°C and intimately mixed with 15 gms. of cut-back Bitumen heated to 70°C, the mixture then being transferred to a wide-necked 500 ccs. flask and allowed to stand for half an hour at 20°C. The flask is then filled with distilled water at 20°C and stored at that temperature for twenty-four hours. The film of binder should adhere firmly to the stone surface.

A modification of this test has been proposed by Oberbach. The selected stone chippings warmed to 35°C are well mixed with 4 per cent. of the binder heated to 100°C, and the mixed chippings placed in a stoppered glass jar for 30 minutes. The jar is then filled with distilled water and placed in a water bath at 40°C for three hours. The proportion of stone metal surface still covered with binder is then evaluated by inspection.

Dr. Knight (loc. cit.) recommends that this modified test can be profitably used in conjunction with the Riedel and Weber Test.

The following test has been evolved by the present writer in an attempt to combine the more advantageous features of the Riedel and Weber and the modified U 37 tests.

180 particles, approx. 3/8 in. size, of the stone metal are selected and warmed to 40°C in a dish and then intimately mixed with 29 per cent. by volume of binder heated to 100°C. The mixture is then allowed to stand for twenty-four hours, and then is transferred to a series of nine boiling tubes, 20 particles in each. The test then proceeds as in the case of Riedel and Weber Test by subjecting the coated stone to a series of Sodium Carbonate solutions as described above except that the solutions in the tube are not boiled over a naked flame but the tubes are placed in a bath of boiling water and retained there for one hour. After cooling, the contents of each tube are carefully examined and the number of stones in each solution (a) completely covered (b) partially stripped of binder (c) completely stripped of binder, are recorded.

The solution concentration is selected which has resulted in stripping the binder from approximately 50 per cent. of the stone metal surface. For this purpose it may be assumed the stones partially stripped are half covered with binder.

A table showing the results obtained by this modified method of Riedel and Weber test on a number of stone metals obtained from different parts of India is given in Table I. This may be compared with figures for various types of road stone metals used in the United Kingdom reported by another modification of the test by Biggs which

is referred to in a pamphlet published by the South Metropolitan Gas Co,[12] see Table 2. Unfortunately, the details of this modification of the Riedel and Weber Test are not available, but a detailed procedure would appear to be similar to that adopted by the present writer.

Dr. B. H. Knight (loc. cit.) also records a series of test results obtained by applying the Riedel and Weber Test to a number of road metals commonly employed in the United Kingdom, coated with various types of binders.

Mallison and Schmidt[13] have evolved a similar test for the adhesion of Road Tars to stone metal chippings in the presence of water, which is specially designed to correlate with full scale road surfacing trials. This method of procedure is as follows :—

3. 5 gms. of Road Tar, heated to 80°C, are mixed with 100 gms. of stone metal. In the case of porous aggregates, e.g., slag, the quantity of Road Tar is increased to 5 gms. The materials are mixed in an open cup or shaken in a tin, the temperature being kept constant.

The mixture is left either for one hour or for twenty-four hours at atmospheric temperature and is then

(1) emptied into a porcelain basin and coverd with water,

(2) heated in an oven to 50°C for half an hour, emptied into a porcelain basin and covered with water.

The time required for various degrees of stripping of the binders by water is noted in each case.

Results from these tests showed that the lapse of 24 hours between the coating and submersion in water invariably led to a considerable improvement in the adhesion of the Road Tar. Comparatively little differences were detected in the adhesive properties of the various types of Road Tars examined, except that adhesion was definitely found superior with the more viscous grades of binder. The Tar Acid and Tar Base contents of the Road Tars were not found to exhibit any definite relationship with the adhesive properties. Similarly, the percentage of Tars soluble in Benzol had no influence on the adhesion nor was support found for Nellensteyn's theory that the quality of a Road Tar depends on certain concentration of micron size 'miscelles'.

In their attempts to classify various rocks in respect of adhesive-

ess to Road Tars, Mallison and Schmidt found a number of important factors which exerted considerable influence on the results:—

(1) Mineralogical composition,

(2) Nature of the cementing magma,

(3) Degree of decomposition and dusty nature of the stone,

(4) Surface conformation and size of specimen,

(5) Presence of alkaline water-soluble compounds on the stone surface. If these soluble compounds are removed by prior extraction with hot water, the adhesivity is definitely improved.

Mallison and Schmidt's classification of mineral rocks in respect of adhesiveness does not altogether tally with the results of Riedel and Weber, but this may be due to a great extent to the different sources of rocks tested.

PART III

Methods of Improving Adhesion of Binders.

From the foregoing theoretical considerations on the nature of adhesion between liquids and solids and the results obtained from the various empirical tests applied to measure the relative degree of adhesion of water and bituminous binders towards stone metals of different types, it has been possible to evolve methods which result in imparting a very definite increase in the adhesive powers of bituminous binders. If such an increase in adhesion can be achieved in practice without undue difficulty or expense then it is clearly a subject which is of much interest to the Road Engineer.

A process which enables road surface treatment to be carried out regardless of inclement weather conditions and at the same time results in an extended life of the bituminous surfacing must merit serious attention from those concerned with road construction.

From what has been discussed earlier in this paper it will be recalled that the resultant adhesion tension of a water-liquid binder-solid system in which water is the displacing fluid is expressed by the equation.

$$S_{sl} - S_{sw} = S_{wl} \cos\theta$$

The smaller the value of the resultant adhesion tension the

greater will be the adhesion of the liquid binder to the solid. Hence to favour this adhesion and to oppose stripping by the action of water we should endeavour to bring about a reduction in the interfacial tension at the solid/binder water interface, or an increase in the interfacial tension at the binder/water interface.

Or, if we consider the problem from the surface energy angle, adhesion between the binder and solid will be promoted by reducing to the lowest potential of surface energy at the solid/binder interface and increasing the surface energy at the binder/water interface.

Dipolar Adhesive Agents.—There are certain chemical compounds which are capable of bringing about a marked reduction of the interfacial tension or surface energy at the solid/binder interface.

These chemicals are essentially dipolar in nature having a negative hydrophilic polar group, usually an hydroxyl ($\overset{1}{OH}$) or fatty acid ($\overset{1}{COOH}$) group and a positive hydrophobic polar group.

The latter is usually a heavy metal (e.g. lead) or an organic grouping of the saturated aliphatic type. These compounds orientate themselves across the solid/binder interface with the hydrophilic group towards the solid and the hydrophobic towards the binder, thus creating an artificially low potential of surface energy at the interface.

This interfacial effect becomes more pronounced with increasing molecular weight of the aliphatic group which is apparently due to the fact that absorption at the solid surface increases with molecular weight.

It has been found also that dibasic fatty acids are much more effective in reducing interfacial energy and in promoting adhesion than monobasic acids.

Mallison and Schmidt (loc cit.) report that the addition of certain waxy ingredients to bitumen and tar e.g. 0·5 per cent. of montan wax or Ozokerite markedly increases the adhesive properties of the binders. This they attribute to a modification in the structure of the binder at the interface, whereby it is rendered porous or foamy. Other observers, however, attribute the action to the presence of high molecular saturated fatty acids in the waxes which appears the more feasible explanation.

Mack,[14] in an interesting paper on the behaviour of Bituminous materials on Road Testing Machines, describes certain tests in which

he incorporated selected adhesive agents with Bitumens and recorded their effects in terms of improved durability of the bituminous mixes in the tracks under test.

The agents thus employed were :—

(1) Lead Naphthenate dissolved in Bitumen to the extent of 2 per cent.

(2) As in (1) and the aggregate treated with 0·1 per cent of a 3 per cent solution of Lead Nitrate.

(3) A solution of 2·4 per cent in equal molecular proportions of lead naphthenate and lead acetate-naphthenate in Bitumen.

The use of these agents was found to result in an increase of durability of the mixes under test of anything from 4 to 15 times depending on the type of Bitumen used and the prevailing temperature.

As the testing temperature rose above 75°F the beneficial action of the agents was found to fall off, a fact which would scarcely favour their adoption in hot climates.

The use of the double salt, lead acetate-naphtenate, is of interest. The mechanism of this agent is that the fatty acetic acid group is hydrophilic and orientates itself on the stone surface and the naphthenic acid group, which is rendered soluble in the bitumen by the presence of lead naphthenate, is hydrophobic and orientates itself on the bitumen side of the interface. The lead molecules therefore act as a binding link between the two oppositely orientated acidic groupings.

Mack reports that the value of a sand/bitumen interfacial tension was reduced from 15 to 3 dynes per cm. by the addition of 2 per cent lead naphthenate. In a second case the interfacial tension was reduced from 18 to minus 3 dynes per cm. by the addition of 2·4 per cent of an equimolecular mixture lead naphthenate and lead acetate-naphthenate. Therefore in this case the agent has actually converted the sand from a hydrophilic to a hydrophobic solid.

The use of such adhesive agents remains so far of academic interest only, and no evidence is forthcoming to show that their use has been successfully adopted in any major road surfacing project. Lee and Carter[15] report unfavourably on the use of iron oleate, lead oleate, ammonium linoleate, aluminium magnesium and ammonium

stearates, as adhesive agents in Tar on bitumen binders for use with wet aggregates.

In contrast to these failure, however, one simple chemical in every day use, readily available, has proved an outstanding success in promoting the adhesion of bituminous binders to wet stone metal. This chemical is hydrated (slaked) lime, Calcium Hydroxide. $Ca(OH)_2$.

The Use of Hydrated Lime as an Adhesive Agent.

The method of employing lime for promoting adhesion of bituminous binder is to apply the lime in powder form to the aggregate prior to the addition of the binder.

The lime is not added to the binder itself for this purpose although it is of interest to note that Hodsman (British Patent 471216 of 1936) suggests incorporating lime in a hot tar or bitumen containing Tar Acids and water under such conditions that at the end of the treatment the free water content of the material is small.

It is claimed that by incorporating from 1·6 per cent up to 20 per cent of lime in this way it confers on the binder various advantageous properties, although no specific claims are laid to improved adhesive action, and no evidence of practical results are so far available.

Considerable evidence is, however, now available in the United Kingdom, America and in India to show that a pre-coating of hydrated lime to the extent of one per cent. by weight on wet stone metal chippings increases the adhesion between the chippings and Road Tars to a marked degree. In the case of Bitumen, to achieve a similar result it is necessary, in addition to the use of Slaked Lime, to add to the Bitumen 2 per cent of a heavy metal soap (e.g. iron oleate) or Sulphonated Castor Oil (Turkey Red Oil). The latter compounds may, however, be added separately to the mix instead of first blending with the bitumen.

A very complete survey of the use of lime with wet aggregates and bituminous binders has been presented in the form of a paper to the Institution of Civil Engineers by A.R. Lee and H.J.E. Carter.[15]

The theory of the action of lime is fully discussed therein and it is stated that in the case of Road Tar wetting a glass surface, the substitution of lime water for distilled water at the surface of contact brings about a drop in the adhesion tension (S_{w1} $Cos\ \theta$) from 11·8 dynes per cm. to 3·0 dynes per cm.

The mechanism whereby lime succeeds in promoting adhesion of binders to wet aggregates is of some interest. Road Tars contain small quantities of Tar Acids—phenol, cresol, etc. which combine at the interface to form Calcium Salts. These Calcium salts of the Tar Acids not only reduce the interfacial tension and favour wetting by the binder but also enable the Road Tar to absorb the water associated with the aggregate in the form of a water-in-tar emulsion. Definite evidence to this effect is available in the form of microphotographs of Tar removed from lime-coated wet-aggregate in which the emulsion particles are clearly seen. The water particles having been extracted from the stone metal into the Road Tar as an emulsion will duly coalesce and be eliminated from the surface of the Tar by evaporation.

This emulsification process of the surface water in the Road Tar demands vigorous action to allow it to proceed. Mére immersion of the lime-treated chippings in the hot tar does not produce adequate wetting by the Tar. Hence in practice well-designed mixers are essential for wet aggregate premixing.

The Calcium salts will, in due course, decompose and the Tar acids will be leached out leaving the lime to function as a filler in the Road Tar, thereby increasing its viscosity and resistance to subsequent stripping from the stone aggregate.

The action of lime is seen, therefore, to be beneficial at every stage, for, firstly, it renders possible quick wetting of hydrophilic stone metal, secondly, it causes the water on the stone metal to be absorbed into the body of the binder and later eliminated from the system and, thirdly, it renders the binder film more viscous and less susceptible to displacement.

It is not necessary, in order to bring about this interfacial action between the lime and the Tar Acids, to specify any greater percentage of Tar Acids in the Road Tar than is permitted in the British Standard Specifications. From practical experience with Indian Road Tars the presence of 0·5 to 1 per cent. of Tar Acids is quite sufficient to yield the desired effect. The presence of higher percentage of Tar Acids is undesirable for a number of other reasons.

In the case of Bitumen, which does not contain Tar Acids, an ingredient has to be added which will react with the lime at the interface and for this reason a heavy metal soap (iron oleate) or Sulphonated Castor Oil (Turkey Red Oil) must be added. The addition of a small percentage of Creosote to Bitumen improves the adhesion obtained and for this reason Cut Back Bitumen containing Creosote may be used with advantage. A number of other effective

wetting agents are available, e.g., Oleic Acid, phenol, calcium phenate etc., but unfortunately they do not result in conferring subsequent resistance to stripping, which is essential.

Quick Lime is even more efficacious than hydrated lime for it will, of course, absorb the surface moisture with greater ease. It is not recommended for use owing to the difficulties involved in its handling. Hydrated lime may also be replaced by Caustic Soda, but although this alkali is more effective in promoting wetting by the binder it has a chemical effect on the structure of the binder which results in considerable decrease in viscosity and consequent inability to resist stripping.

It is important that the slaked lime should be a fat, pure variety. Hydraulic and kanker limes are quite useless as adhesive agents. Tests on various Indian slaked limes reveal the following order of merit as adhesion promoters:

(1) Sylhet Lime	(Assam)
(2) Katni ,,	(C. P.)
(3) Sanjani ,,	(Punjab)
(4) Sutna ,,	(C. P.)
(5) Mihar ,,	,,
(6) Bisra Lime	(Bihar)

The actual percentage of slaked lime to be specified for use with wet aggregate is found to vary to some extent with the nature of the stone. Quartzite and porphyritic stones which are more difficult to coat with binder require more slaked lime to achieve satisfactory results than limestones, slags, etc. The percentage of Slaked Lime in such cases may be increased to 1.5 per cent by weight.

If sand or fine aggregate only is being used the percentage of lime should be increased to 2 per cent.

It should be noted that inert fillers such as china clay, etc., do not behave as adhesive agents in a manner similar to slaked lime. The basic nature of the latter is obviously a primary factor in fulfilling its function.

Another material easily available which can, however, be substituted for lime is Portland Cement. From experimental trials

carried out in India, cement has been found a satisfactory adhesive agent although not quite so effective as slaked lime. In order to achieve similar results quantities specified for slaked lime should be increased by 25 per cent to 50 per cent in the case of Portland Cement. Under normal conditions therefore, it would not be an economical proposition to utilise cement in place of slaked lime.

In certain instances where lime was not available on projects caked cement rejected for concrete work has been successfully employed with Road Tar for wet aggregate work at 2 per cent by weight.

Viscosity of Binders for Wet Aggregate Treatment.

The treatment of wet aggregates can only be satisfactorily achieved with binders possessing a certain minimum degree of fluidity, i.e. the viscosity of binder must fall below a certain maximum figure. Such maximum viscosity varies with the prevailing atmospheric temperature, and is a very important factor which must be taken into consideration.

Lee and Carter (loc. cit.) include in their paper and table of permissible viscosity ranges for the treatment of certain selected stone metals of small and large size at a prevailing atmospheric temperature range of 5° to 20°C (41—68°F). The more difficult stones to coat should, generally speaking, be premixed with a somewhat richer coating of lower viscosity binder than stones of normal wetting properties. The limit for quantity stipulated for coarse gradings (2 in.) are 7 to 10 gallons per ton of aggregate which is approximately equivalent to 4—5½ lbs. of Road Tar per cu. ft.

For finer gradings (passing ¾ in. to coarse sand) of low void content the quantities of binder recommended are 12-15 gallons per ton of aggregate equivalent to 6½—8½ lbs. of Road Tar per cu. ft.

The viscosity limits recommended for binders fall between 10 seconds at the lower temperatures and 60 seconds at the higher temperatures, measured at 30°C. This means that the Road Tars employed for wet aggregate treatment in the United Kingdom vary from British Standard Specification Road Tar No. 1 (viscosity range 10—40 seconds at 30°C to the thinner range of Road Tar No. 1 (viscosity range 40—125 seconds at 30°C).

In terms of Equiviscous Temperature—EVT (i.e., the temperature at which 50 mls. binder has a time flow of 50 seconds in the standard Tar viscometer) the recommended viscosity range may be expressed as 10°—30°C.

When we have to consider wet aggregate treatment in India we are faced with very different conditions climatically. Considerable limitations are imposed on this process in temperate climates as wet weather conditions are usually associated with the winter months and cold temperatures.

In India, however, the wet monsoon season occurs during the summer months and over a large area of the subcontinent wet weather conditions are associated with warm temperatures. For this reason wet aggregate treatment in many parts of India would appear to be of relatively greater potential value than in colder climes. The average prevailing temperature range in India during the monsoon season may be assumed as 20°—35°C (68°—95°F). In consequence it is possible to employ for this treatment binders of higher viscosity than those employed in the United Kingdom.

In Bengal, using wet Basalt trap metal treated with lime, Road Tar No. 3 has been found definitely superior to Road Tar No. 2 as regards adhesion.

The viscosity range of Road Tars recommended for wet aggregate treatment in India is 70 seconds at 35°C to 50 seconds at 45°C. This range, expressed in terms of Equiviscous Temperature (E.V.T.), is 37° to 45°C and covers the grades Road Tar No. 3 (B S.S.) and Road Tar No. 3A, a special grade available from Indian manufacturers.

Generally speaking Road Tar No. 3 should be employed for surface painting and the more viscous Road Tar No. 3A for premix treatment.

For lower temperatures which may prevail at high altitudes (over 5000 ft. above sea level) a lower viscosity range of 32°—35°C E.V.T. may be specified with advantage which covers the thicker range of Road Tar No. 2 (B.S.S.)

The temperatures to which the Road Tars are heated before application need not differ materially from those recommended for dry weather conditions.

Field Trials with Wet Aggregates and Lime Trials in the United Kingdom.—Lee and Carter in their paper describe some full-scale trials laid on the Colnbrook by-pass in the U.K. in September and October 1942. These trials consisted of premix carpets, ¾ in. consolidated thickness, laid with granite and gravel aggregates. Wet aggregates were treated with slaked lime before an addition of Tar and Bitumen binders were laid adjacent to similar carpets

constructed with bone dry aggregate. After the lapse of twelve months no distinction could be drawn between the sections laid with dry or with lime-treated wet aggregate.

These authors also report the satisfactory construction of wet sand carpets up to 4 in. thickness for aerodrome runways and perimeter tracks.

These mixes have been produced in batch and continuous mixers and contain 2 per cent. of Slaked Lime and 5.8 per cent. of cut-back Bitumen and Road Tar Binders.

Surface Treatment Trials with Lime and Road Tar In India.—In India wet aggregate and lime experiments were first carried out with Road Tar binders in Calcutta in July 1942 on the Garialiat Road with the permission and co-operation of the Calcutta Improvement Trust authorities.

The treatments consisted of surface painting over waterbound macadam constructed with Pakur trap-metal and building debris as blindage.

Sections were laid with

(a) Road Tar No. 2 at 45 lbs. per 100 sq. ft. and 5 cu. ft. of $\frac{3}{4}$ in. Pakur stone chippings, and

(b) Road Tar No. 3 at 50 lbs. per 100 sq. ft. and 5 cu. ft. of $\frac{3}{4}$ in. Pakur stone chippings.

These two sections were subdivided as follows:—

(i) No lime used on waterbound or on chippings.

(ii) Slaked Lime spread on the waterbound prior to the application of Road Tar at 9, 12 and 15 lbs. per 100 sq. ft. with plain wet chippings.

(iii) As in (i) and (ii) but wet chippings coated with 0.75 per cent. of slaked lime by weight.

These sections were laid under wet monsoon conditions. Sylhet Lime was used and the Road Tar was spread over the lime by means of perforated tins.

A final section was laid with a tack coat of 40 lbs. of Road Tar No. 3 per 100 sq. ft. on the waterbound macadam and premixed chips applied which had been treated with 0.75 per cent. of slaked lime and 5 lbs. of Road Tar No. 3 per cu. ft.

The sections were opened to traffic on the day following application. The traffic carried was moderately heavy, mixed bullock carts and military motor vehicles.

Within a few days under the influence of a spell of hot weather the Road Tar was observed to flush up very quickly in the sections on which lime was spread and some superficial bleeding occurred, although the rates of application of the Road Tar are those normally employed under dry weather conditions. It was clear that the effect of spreading lime on the wet waterbound macadam was to check the initial penetrations of the binder into the waterbound macadam. Although these sections soon showed signs of maturing it was decided to extend the experiments applying Road Tar No. 2 in somewhat reduced quantities—40 lbs. and 35 lbs. per 100 sq. ft. with the slaked lime applications as previously, and test sections with reduced quantities of binder were laid in August 1942 during a spell of fine weather. The waterbound and chippings were maintained saturated with water during the laying of the experiments.

These sections did not exhibit any tendency to bleed under the hot sun. The sections on which 40 lbs. per 100 sq. ft. were laid flushed up well, but the sections with 35 lbs. per 100 sq. ft. appeared deficient in binder.

About six weeks after the first sections were laid sample cuts were made to detect the degree of penetration of the Road Tar into the waterbound macadam. This was found to vary between 1½ in. to 2 in. and had not therefore been adversely affected by the spreading of lime, although the latter appears to check initial penetration which is a desirable feature with porous blindage in the waterbound macadam.

After about 3 months had elapsed the section on which no lime had been used showed definite signs of deterioration, the sections laid with Road Tar No. 2 proving definitely less durable than those laid with Road Tar No. 3. The sections on which 35 lbs. of Road Tar No. 2 per 100 sq. ft. had been laid also commenced to fail especially where no lime was used.

The sections on which Slaked Lime was applied, with Road Tar No. 3, were standing well after 9 months. The sections on which chippings were applied premixed appear particularly satisfactory.

In February 1944, after the expiry of 18 months, inspection revealed serious deterioration of sections on which Road Tar No. 2 was applied. The sections laid with premixed chippings (lime coated) remained the best but the sections on which surface painting with Road Tar No. 3 and lime had been applied were satisfactory except for a number of local subsidences immediately above a main drainage sewer installed just prior to the construction of the waterbound macadam.

This trial served to illustrate the effectiveness of lime treatment and to enable specifications for surface painting on wet waterbound macadam with wet chippings to be evolved.

The following general conclusions were drawn from the experiment :—

1. The spreading of slaked lime on the waterbound macadam prior to surface painting with Road Tar under wet conditions proved definitely successful and beneficial. The quantity of slaked lime to be applied is between 5 & 10 lbs. per 100 sq. ft. according to the nature of the waterbound macadam.

2. The coating of the wet chippings with slaked lime at 0.75 to 1.0 per cent. before spreading yields a further improvement although it is not essential.

3. Road Tar No. 3 is definitely superior to Road Tar No. 2 for wet weather surface painting owing to its higher viscosity being better able to withstand the stripping effects of water.

The minimum application of Road Tar with $\frac{3}{4}$ in. chippings should be 45 lbs. per 100 sq. ft. under the conditions of this test.

4. The best results were obtained by premixing the chippings with Road Tar No. 3 after a preliminary coating with slaked lime and spreading them on a tack coat of Road Tar No. 3 applied to the untreated damp waterbound macadam.

Runway Construction with Road Tar, Wet Aggregate and Lime in India.

Simultaneously with the Surface Painting Experiments described in the previous paragraph, the Central Public Works Dept.,

Eastern Aviation Circle, adopted a wet aggregate specification for Tar Premix Carpet construction on several projects in Bengal. These projects, being of an urgent strategic nature, had to proceed irrespective of weather conditions. They therefore presented a good opportunity to test the efficacy of the wet aggregate formula for premix under conditions obtaining in practice.

Runway No. 1 : Job No. 111 (S. E. Bengal)

Area 6,000 ft. × 150 ft.

Started 3-7-42; Completed 22-10-42

Base : 3 layers brick, two flat, one on edge : Thickness 11 ins : Brick joints filled with sand.

Tack Coat (including grouting of Brick Joints) 40 lbs. Road Tar No. 3 per 100 sq. ft.

Carpet : Stone chippings, $\frac{3}{4}$ in.—$\frac{1}{4}$ in. grading coated with slaked lime (Sutna) (0.75 per cent. by weight) and premixed in hand mixers and mechanical mixers with 5 lbs. Road Tar No. 3A heated to 220°F. The premixed chippings were spread and consolidated at 13 cu. ft. per 100 sq. ft.

Liquid Seal was provided at 20 lbs. Road Tar No. 3A blinded with sand at 2 cu. ft.

This runway set up very well and, although laid continuously throughout the rainy season, the adhesion of binder to stone was excellent and no tendency to poor coating by the binder or stripping was in evidence.

The runway has since been in continuous service through two subsequent monsoons under medium weight aircraft and remains in sound condition.

A liquid seal was again provided in March 1944 to ensure complete waterproofing.

Runway No. 2: Job No. 142 (West Bengal)

Area 6,000 ft. × 150 ft. approx. : 50 per cent. laid with Tar Premix Carpet wet aggregate specification and 50 per cent. Tar Premix Carpet dry weather specification.

Started 2-3-43 : Completed 27-8-43

Base 4½ ins. stone waterbound macadam over 6 ins. boulder soling.

Tack Coat: 40 lbs. Road Tar No. 3 per 100 sq. ft. laid over 9 lbs. slaked lime (Sutna)

Carpet: Stone chippings ¾ in.—¼ in. grading, coated with slaked lime @ 0.75 per cent. by weight were premixed in hand and mechanical mixers with 5 lbs. of Road Tar No. 3A heated at 220°F. The premixed chippings were spread at 13 cu. ft. per 100 sq. ft.

Liquid Seal: (Camouflage specification) provided at 30 lbs. Road Tar No. 3A per 100 sq. ft. and moorum blinding at 2 cu. ft. per 100 sq. ft.

This runway has since been carrying operating aircraft up to the heaviest load types quite satisfactorily. No distinction can be drawn between lengths laid to the wet aggregate and dry aggregate specifications, both being equally effective.

Runway No. 3: Job No. 131 (S.W. Bengal)

Area 4,800 ft. × 150 ft. approx. : 50 per cent. laid with Tar Premix Carpet wet aggregate specification and 50 per cent. Tar Premix Carpet dry weather specification.

Started 25/5/43 : Completed 2/8/43

Details of construction were identical with Runway No. 2 as above. This runway has also given good service under the heaviest load aircraft although subsidence has occurred in some places necessitating building up to correct camber, which weakness was in no way attributable to the Premix Carpet. No difference was in evidence between the performance of the wet aggregate and dry aggregate specifications.

Wet Aggregate Surface Painting Experiments carried out by the Bengal C. and W. Dept. in 1943.

Burdwan Division:

Location:	Burdwan-Kalna Road	(i) Mile 1 Furlongs 1 & 2
		(ii) ,, 2 ,, 7 & 8
		(iii) ,, 3 ,, 1 & 2

Started 12-7-43: Completed 30-7-43

Base: Sections Nos. (i) & (ii) were of stone waterbound macadam previously stabilised with Road Tar No. 2 and sand.

Treatment: Slaked lime (Katni) was brushed over the surface at 6—8 lbs. per 100 sq. ft: Road Tar No. 3A applied at 40 lbs. per 100 sq. ft.

Stone chippings, graded $\frac{3}{4}$ in. downwards, were coated with 0.75 per cent. by weight of slaked lime spread at 5 lbs. per 100 sq. ft. and rolled.

Base: Section (iii) was of untreated stone waterbound macadam.

Treatment: Slaked lime (Katni) was spread over the waterbound macadam at 10 lbs. per 100 sq. ft.

Road Tar No. 3A was then applied at 50 lbs. per 100 sq. ft. heated to 220°F.

Stone chippings, graded $\frac{3}{4}$ in. size downwards, were coated with 0.75 per cent. by weight of slaked lime and spread at 5 lbs. per 100 sq. ft. and rolled.

These surfaces have stood well under mixed bullock cart and lorry traffic of medium intensity and they were officially reported in sound condition in May 1944. The adhesion of Road Tar to the chippings proved quite satisfactory.

2. *Location:* City Division: Cathedral Road (Western half width)

Area 500 ft. x 12 ft.

Completed on 30-6-43.

Base : Bituminous surface painting showing appreciable wear under bullock cart traffic on the flank.

Treatment for Renewal Coat.

Tack coat of Road Tar No. 3A spread at 20 lbs. per cu. ft. with *no* lime treatment.

Chippings graded ¾ in.—½ in. were coated at 0.75 per cent. of slaked lime and premixed with 5 lbs. of Road Tar No. 3A per 100 sq. ft. The chippings were spread at 7 to 8 cu. ft. per 100 sq. ft. and rolled.

The surface after 14 months is in a generally satisfactory condition and standing up to heavy mixed traffic in a manner which compares favourably with dry weather treatment laid in adjoining lengths on the same road. Some local defects were however detected a few months after the surface treatment had been completed. At these points there was found to be no bond between the premixed chippings and the base, which in such instances was found to retain moisture due to serious wear and local destruction of the original waterproof seal. The conclusion drawn from this experience is that, in renewal coat work, lime should be spread on any areas where the original waterproof layer of binder has been destroyed prior to the application of the tack coat. This should ensure the bonding of premixed chippings with the base.

It was hoped to arrange further extensive trials with wet aggregate treatment with the Central and Provincial Public Works Depts. during the monsoon season of 1944, but unfortunately with little success, so far as the Provincial P.W.Ds. are concerned. This has been due for the most part to (1) lack of Road Tar, (2) lack of stone chipping and (3) lack of Road surfacing equipment.

The Central P.W.D. Aviation Divisions, Bengal, have during the monsoon season of 1944 continued to adopt Road Tar surface treatment with wet chippings and lime in the general programme of surfacing dispersal tracks and approach roads on a number of aerodrome schemes. Surface treatment over both stone metal and laterite waterbound are being carried out to the following specifications standardised by the manufacturers, with initially satisfactory results:—

Surface Dressing with Road Tar and Wet Aggregate 1st Coat Treatment.

(*i*) *Preparation of the Road Surface.*

The surface should be swept free of excess blindage and water with long handled brooms to expose a clean stone metal surface. Wire brushes may be used to remove caked mud but not so as to destroy good interlocking.

(*ii*) *Application of slaked lime.*

The best slaked lime available in dry powdered form is dusted uniformly over the surface by hand at the rate of 5—10 lbs. per 100 sq. ft. A long handled broom may be used to help distribute the lime evenly and to remove any lumps formed.

(*iii*) *Application of the Road Tar.*

Road Tar No. 3 or 3A (thinner grades are not recommended) heated to 220°F is then applied from a perforated sprinkling can over the lime covered surface at the rate of 45—50 lbs. per 100 sq. ft. The Road Tar may be brushed out to ensure an even application.

(*iv*) *Application of Blindage.*

Stone chips or gravel of the specified size (normally ¾" in.) are coated with slaked lime as follows :—

The chippings, washed free of any adhering mud, if necessary, are loaded into a mixer and given a coating of slaked lime at the rate of 0·75 per cent. by weight. Rotation in a hand mixing drum for 1 minute is sufficient to ensure a good coating of lime on the damp chips.

The lime-coated chips are then spread evenly over the Road Tar application as specified, e.g., 5/6 cu. ft. per 100 sq. ft.

Rolling is provided with a 6 or 8-ton Roller and traffic may be allowed over the surface as soon as rolling is complete. Average requirement of lime for the above specification per mile of road 12ft. wide is 63½ cwts.

2nd or Renewal Coat Treatment with Wet Aggregate.

(*i*) *Preparation of the Road Surface.*

In the case of 2nd or renewal coat application over a previously

treated surface wet weather conditions do not provide the same degree of difficulties as with 1st coat treatment. Previously treated surfaces dry quickly after rain and it is merely necessary to sweep off all water lying in depressions. Where the surface is seriously worn and the stone metal of the base is exposed, a light application of slaked lime at 8 lbs. per 100 sq. ft. should be given prior to the application of Road Tar. Pot holes, if present, should have been previously repaired with premix metal or patch painting as per standard specification.

(*ii*) *Application of the Road Tar.*

Road Tar No. 3 or 3A heated to 200°F is poured with a perforated can or sprayed at the rate specified in the normal manner.

(*iii*) *Application of Blindage.*

Stone chips of the specified size (normally ½ in.) are coated with slaked lime as follows—

The chippings, washed free of any adhering mud, if necessary, are loaded into a mixer and given a coating of slaked lime at the rate of 0·75 per cent. by weight.

Rotation in a hand mixing drum for 1 minute is sufficient to ensure a good coating of lime on the damp chips.

The lime-coated chips are then spread evenly over the Road Tar application as specified, e.g., 4½ cu. ft. per 100 sq. ft. Rolling is provided with a 6 or 8-ton Roller and traffic may be allowed over the surface as soon as rolling is complete. Average requirements of lime for the above specification per mile of Road 12 ft. wide is 25½ cwts.

The Punjab P.W.D. provided facilities in August 1944 for some interesting surface painting tests to be carried out under monsoon conditions with wet aggregate and Road Tar in the Simla district, on the Circular Road, Simla, at the junction with the Lower Road. One furlong each of original first coat and simultaneous two-coat treatment with Road Tar No. 3 and wet aggregate were laid to the following specifications:—

1. Specification for First Coat Surface Treatment with Wet Aggregate.

1st Furlong from Junction—Road width 14 ft.

(i) The existing waterbound macadam surface was swept

free of excess blindage and water, long-handled brooms being used for the purpose. Wire brushes were used to remove caked mud but not in such a way as to destroy good interlocking.

(ii) Slaked lime (Sanjani) in dry powdered form was dusted over the surface by hand at the rate of 6 to 8 lbs. per 100 sq. ft.

Note.—The optimum quantity of slaked lime depends on the roughness of the waterbound surface, the quantity of water present and the nature of the chippings. The precise quantity is decided after inspecting local conditions.

(iii) Road Tar No. 3 heated to 220°F was then sprayed evenly over the lime covered surface at the rate of 36 and 44 lbs. per 100 sq. ft.

(iv) Stone chippings of hard quality graded from ¾ in. to ¼ in. were coated with slaked lime as follows :—

The chippings were washed free of any adhering mud and loaded into a mixer and given a coating of slaked lime at 0.75 by weight. One minute in the hand-mixing drum is sufficient to ensure a good coating of lime on the wet chippings.

(v) The lime-coated chips were then spread evenly over the Road Tar application at the rate of 5 cu. ft. per 100 sq. ft.

(vi) Rolling was provided with a 10-ton Roller and traffic allowed over the surface as soon as rolling was complete.

2. Specification for Simultaneous Two-Coat Treatment with Wet Aggregate.

2nd Furlong from Junction.

(i) The existing waterbound macadam surface was swept free of excess blindage and water, long-handled brooms being used for the purpose. Wire brushes were used to remove caked mud but not in such a way as to destroy good interlocking.

(ii) Slaked lime (Sanjani) in dry powdered form was dusted

over the surface by hand at the rate of 8 lbs. per 100 sq. ft.

Note:—The optimum quantity of slaked lime depends on the roughness of the waterbound surface, the quantity of water present and the nature of the chippings. The precise quantity will be decided after inspecting local conditions.

(iii) Road Tar No. 3 heated to 220°F was then sprinkled over the lime-covered surface at the rate of 44 lbs. per 100 sq. ft.

(iv) Stone chippings of hard quality (Chandigarh), graded as under:—

Passing $\frac{3}{4}$in. sq. mesh, retained on $\frac{1}{2}$in. = 2/3rds
" $\frac{1}{2}$in. " " " " $\frac{1}{4}$in. = 1/3rd

were given a coating of slaked lime in accordance with the method described in previous specification, Para (iv).

(v) The lime-coated chips were then to be spread evenly over the Road Tar application at the rate of 4 cu. ft. per 100 sq. ft.

(vi) Rolled twice with a 10-Ton Roller.

(vii) Immediately after rolling, Road Tar No. 3 heated to 210°F was applied at 28 lbs. per 100 sq. ft.

(viii) $2\frac{1}{2}$ to 3 cu. ft. of lime-coated stone chippings were then spread graded as under:—

Passing $\frac{1}{2}$in. sq. mesh, retained on $\frac{1}{4}$in. = 2/3rds
" $\frac{1}{4}$in. " " " " 1/16 in. = 1/3rd

(ix) Rolled to set.

(x) Opened to traffic after 24 hours.

On the Kalka-Simla Road Mile 88 furlongs 1 to 4 (near Tara Devi), experiments were carried with Renewal coat treatment

using Road Tar No. 3, wet chippings, and lime over previous bituminous surface treatment.

3. The Renewal Coat Specification adopted was as follows:—

(i) All water lying in depressions was swept off. Where the surface was seriously worn and the stone metal of the base exposed a light application of Slaked Lime was given at 8 lbs. per 100 sq. ft. prior to the application of the Road Tar.

(ii) Road Tar No. 3 heated to 200°F was sprayed at the rate specified for each experimental length.

(iii) Stone chippings of the specified gradings were coated with Slaked Lime as follows:—

The chippings were washed free of any adhering mud, loaded into a mixer and given a coating of slaked lime at 0.75 per cent. by weight. One minute in the hand-mixing drum is sufficient to ensure a good coating of lime on the wet chips.

(iv) The lime-coated chips, in accordance with the specified quantity, were then spread evenly over the Road Tar application.

(v) Rolling was provided by a 10-ton roller and traffic allowed over the finished surface as soon as rolling was complete.

Site	Road Tar No. 3 Quantity per 100 sq. ft. in lbs.	Stone Chippings			Percentage by weight of lime per c. ft. of Coating Chips.
		Type	Size	Qty. in c. ft. per 100 sq.ft.	
Mile 88 Fg. 1	32	Local	½in. to 1/8in.	4·5	0·75
Fg. 2	32	,,	,,	4·0	0·75
	28	,,	,,	3·5	0·75
Fg. 3	32	,,	,,	4·5	No lime used.
Fg. 4	28	Kalka Gravel	⅜in. to 1/8in.	4·0	0.75 (Sanjani)

General Remarks on the Possibilities of Wet Aggregate Treatment with Road Tars in India.

1. Climatic conditions in certain parts of India, where the rainy season is associated with warm prevailing temperatures, favour the successful treatment of wet aggregate using lime and more viscous grade of Road Tar.

2. Lime treatment may be simply and economically incorporated in both surface painting or premix carpet specifications.

3. Wet aggregate treatment permits bituminous surfacing projects of an urgent or important nature to proceed throughout the rainy season without adverse effects on the results.

4. Deterioration of bituminous surfaces in India is most noticeable during the rainy season, and it is generally desirable that repairs should be taken up as soon as possible after worn patches and pot holes begin to appear. Use of lime and premix chippings precoated with lime enables effective patch repairs to proceed with during the rains and thereby reduces deterioration of road surfaces to a minimum.

5. It is possible that the inclusion of lime in bituminous binders confers a longer life on the various types of binders used in road construction and that, in consequence, surfaces laid to the wet aggregate and lime specifications will prove more durable than surfaces laid with some binders and dry aggregates. Conclusions on this point can be drawn after a number of years have elapsed, and it is hoped that in the near future it will be possible for widespread and properly controlled field tests to be initiated in different parts of India using wet aggregate and lime in conjunction with bituminous binders on road lengths permitting regular observation.

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TABLE I

Results of Adhesion Tests on Various Indian Stone Metals for suitability for Tar Surface Treatment

Province:	Locality:	Geological Name:	Degree of Adhesion by Modified Riedel & Weber Tests	Water Absorption per cent.	Hardness:	Remarks on Suitability for Tar Treatment;
ASSAM	Dibrugarh.	Quartzite.	0	—	Moderate.	Not recommended.
	Sylhet.	Trap.	3	—	Hard.	Good.
	Palel-Tamu Road	Limestone.	8	0·12	Hard.	Very Good.
BENGAL	Pakur.	Basalt.	2	0·58	VeryHard	Good with heavier application of tar than normal in wet climate.
	Darjeeling.	Fellspathic quartzite	1	0·24	Moderate.	Fair.
BOMBAY	Ratnagiri.	Basalt Trap.	1	1·21	Hard.	Satisfactory.
	Yervada.	Amphibolite.	6	1·27	Hard.	Satisfactory.
	Ahmednagar.	Pyroxene.	2	1·16	Hard.	Satisfactory.
	Ankola.	Coarse grained gneiss	0	0·03	Hard.	Unsatisfactory.
MADRAS	Chickrayapuram.	Pyroxene Granite.	3	0·21	Hard.	Satisfactory for Tar surfacing.
	Anantapur.	Quartzite.	0	0·18	Hard.	Test results indicate unsuitability but good results have been obtained in dry climate.
	Bellary.	Granite Gneiss.	0	0·17	Hard.	-do-

TABLE I (*Continued*)

Province:	Locality:	Geological Name:	Degree of Adhesion by Modified Riedel & Weber Tests	Water Absorption per cent	Hardness.	Remarks on Suitability for Tar Treatment:
MADRAS	Pallavaram	Ferruginous Quartzite.	5	0·57	Hard.	Test Results indicate good suitability but in practice found to yield poor results in wet climate.
	Tinnevelly.	Horn-blend Granite.	2	0·21	Hard	Satisfactory.
	Rajahmandry.	Finegrained Dolerite	2	2·3	Moderate.	Satisfactory with heavier application than normal in wet climate.
	Madura.	Gneiss.	0	0·36	Moderate.	Test results indicate unsuitability but in practice fairly satisfactory results obtained.
PUNJAB	Hindupur.	Gneiss. (Garnet)	1	0·23	Hard.	Satisfactory.
	Pathankote.	Mixed Quartzite	0	0·2	Hard.	Tests indicate poor adhesion but very good results obtained in a dry climate.
DELHI	Chandigarh.	—	3	0·16	Hard.	Very Good.
	Delhi.	Ferruginous and micaceous Quartzite.	1	0·18	Moderate.	Fair.

TABLE II.

Results of Adhesion Tests on Various Road Stones in the United Kingdom (Extracted from "The Preparation of Thin Tar Carpets" South Metropolitan Gas Co.)

Type of Road Stone:	**Degree of Adhesion by Modified Riedel and Weber Test.**
Slag.	10
Ragstone (Kent).	9
Penlee Granite.	9
Limestone (Plymouth).	8
Gravel (Surrey).	7
Limestone (Northants).	7
Ragstone (Kent).	7
Granite (Penmaenrhos).	6
,, (Cornwall).	6
,, (N.W. Wales).	5
Gravel (Kent).	4
Quartzite (Warwickshire).	3
Granite (Wales)	2
Gravel (Hants)	1

JOURNAL OF THE INDIAN ROADS CONGRESS

NO. —2 NINTH SESSION

JANUARY, 1945.

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INDIAN ROADS CONGRESS.

PAPER NO. IX - 100.

1944.

STABLE CAUSEWAYS ON UNSTABLE FOUNDATION SOILS

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1. Causeways are, perhaps, the precursors of bridges. Whereas the technique of design for the bridges has advanced far and wide and new developments are on a progressive increase, the technique for the design of causeways never received the attention it deserved. The answer, probably, lies in the fact that the initiative and lead established by the Railway Engineer in this country in the matter of bridges was accepted by the Road Engineer as a *fait accompli* and the solution of his own problems. The difference that characterises the two undertakings was not fully appreciated. The Railways are commercial or quasi-commercial undertakings. So long as the receipts justified the outlay on the project, the details little mattered. In the interest of continuity of service under the most adverse and remote circumstances, high factors of safety were allowed and to secure rapidity in construction, the use of pre-fabricated steel girders was freely resorted to. These standards necessarily raised the cost of road bridges both in initial outlay and upkeep charges with the net result that where circumstances did permit a departure to a cheaper alternative by a lowering of the assumed standard, no advantage was taken and many a fine road, for want of a crossing or two along it, lies permanently scarred and disfigured, not to speak of the investment that remains only partially utilised. The credit for pioneer work and breaking the shackles in this respect goes to the engineers of the Central Provinces who over two decades ago launched out the scheme of constructing submersible bridges over their major rivers and, thus, set the pace for the development of high and low submersible structures.

2. Causeways are quite an institution in Road Engineering but they mostly exist in a primitive form. They are found usually along unimportant roads and have varying spans, arch or slab coverings, and massive piers and abutments. One care that seems to have been most scrupulously taken, is their founding upon rock or a soil bordering upon rock. The anxiety in this respect

has very often been so extreme that in quest of securing solid foundations, detours have been made from the obviously correct alignment even at the expense of introducing acute kinks and hair-pin bends in the approach roads. Whatever may be said about this defect from the point of view of the modern fast moving traffic, the fact remains that if this initial care as regards foundations had not been exercised, their very survival through abnormal catastrophes was out of question. As regards the ventage, it was fully provided where rock was available and directly a pocket of soft soil was encountered, a solid retaining wall was the feature, something entirely contrary to what was required. If the old causeways are carefully examined, unless even their wings are founded upon rock, traces of undermining action by free vortices working along the down-stream side of the wings will be amply evident either in the shape of an over-hanging wall or a collapsed one. Why this should be so will be explained presently.

3. My presumption may be wrong but my conviction has been that there is a lot of prejudice against the adoption of causeways on account of the ethereal standard for bridges observed hitherto. Before a widespread adoption could be advocated it was necessary to establish the advantages claimed for them. This brought one face to face with two problems; the study of the flood flow conditions of the river and the basis upon which the members of the structure were to be designed.

4. The determination of the rate of discharge from a catchment basin at a fixed point is a very complicated matter and no attempt has so far succeeded in laying down a law for it. It is understandable that this should be so, for the factors so vary and are so indeterminate in character. Different catchment basins of equal magnitude may give quite different discharges, for it is very unlikely that the intensity, duration and frequency of rainfall, the shape of the catchment basin, its declivity, the geological formations at and underlying the surface and the vegetable growth, will happen to be one and the same under all conditions. Scientific knowledge has progressed so far as to determine to a degree of approximation the total yield or the maximum rate of discharge from a catchment basin but no correlation has been effected as yet between the rate of rainfall in a zone of the catchment basin and the discharge resulting from it at a selected point lower down it. With this grave deficiency in our knowledge we lack the means of determining the flood flow regime of a drainage area. Therefore there is no alternative but to observe over a number of years the behaviour of the flood at the selected site for the causeway and thereafter to determine the height to which it should be raised to cut out the

peak periods. What I have stated is a time devouring process, but those who interest themselves seriously in this problem will find that once the initial stages are mastered by observation on a few typical catchment basins, the solutions will dictate themselves on their own.

5. Late Mr. D. Nilsson in his excellent and thought-provoking paper under the title of "some Notes on Submersible Bridges"* has stated that the forces that act upon a submersible bridge are:—

(i) that due to the static head on account of the afflux on the upstream side and the trough of the standing wave on the down stream.

(ii) that due to the impact of the water and debris.

(iii) that due to the eddy motion at the back of the piers.

(iv) that due to the friction of the water against the piers and soffit, and

(v) that (uplift) due to a head equal approximately to the thickness of the superstructure plus the afflux.

6. In his analysis he has pointed out that of all the horizontal forces, No. (i) is "very much the greatest". On consideration it will be found that the magnitude may be large but it is infinitesimal compared to the counteracting resistance offered by the gravity of the structure. The pith of the thesis of late Mr. D. Nilsson appears to be that a submerged bridge remains in a state of static balance owing to the cancelling forces of the head of water.

7. To establish whether this is so, qualitative experiments were undertaken in 1939 in the Hydraulics Laboratory of the Osmania Engineering College under the expert guidance of Dr. S.P. Raju, Head of the Department of Hydraulics and, since then, the Principal of the College. The results obtained have been reported by Dr. S.P. Raju in the form of papers to the Sessions of the Institution of Engineers, Hyderabad Centre. Without referring to them in extenso, I shall quote concisely the problem investigated and the results obtained.

8. For adequate design of the superstructure of a bridge or causeway, it is necessary to know the extent of the super-incumbent load likely to come upon it. In a structure under submergence, the state of balance is obtained provided the flow through the vents has a stream line motion. But there are three factors that could be

*Paper No. 1—Fifth proceedings of the Indian Roads Congress.

assumed to interfere with this condition viz. increased velocity, frictional resistance and eddies caused by the overtopping water. It is a well-known phenomenon that a certain amount of air is always present in a stream of water. With the disturbance in flow due to the increased velocity and the frictional resistance offered by the masonry, the air is subject to detachment and collection at the highest point i.e. under-side the decking. This trapped air, perhaps, moves with the pulsations of flow until it is discharged from the barrel. Likewise, the overtopping water, when in contact with the energized ventage water, causes a standing wave, the trough of which works back into a part of the barrel. These pulsations are, no doubt, momentary but, all the same, they give rise to pulsating momentary vacuums when the static balance of the forces is destroyed and the head of overtopping water freely exerts its pressure. The qualitative experiments of Dr. S. P. Raju have proved, conclusively, that the stated condition does not set in so long as the hyper-critical velocity is not exceeded and this velocity was, roughly, determined as 23 feet per second. Since, normally, our river beds are incapable of developing the hyper-critical velocity, the design of the superstructure of a submersible bridge or causeway calls for no special treatment other than that observed in the case of an insubmersible structure. Another very useful result that came to be comprehended was the manner in which the overtopping and ventage waters dissipated their energy.

9. The ventage water on exit has a tendency of forming a free vortex which travels sideways, both clockwise and counter-clockwise. If the spacing between the vents is small the impinging action of the jets neutralises each other; but in case the spacings are large giving rise to a still water region, the free vortex dissipates its energy vertically by scooping up the soil. The overtopping water dissipates its energy horizontally by forming rollers which lose their intensity as they travel forward. The first two rollers are destructive in action and remove the soil in front of them and also that loosened by the free vortex. The comprehension of these two factors at once substantiates two important things. One is that so long as a submersible structure is founded upon rock, the design of the substructure calls for no special treatment other than that required in an insubmersible structure. The other is that a submersible structure founded upon a friable soil can survive provided the necessary protection is furnished to the foundations.

10. The selection of site for a causeway or a submersible bridge needs greater investigation than that of an insubmersible bridge. Besides the straightness of the course above and below the site, absence of shoals, and holes across the cross section, the topography of the banks is the most important feature and this alone determines

the height to which the structure can be safely raised. Instead of resorting to script, the following sketches will, I hope, be more communicative.

IDEAL SITE FOR A BRIDGE

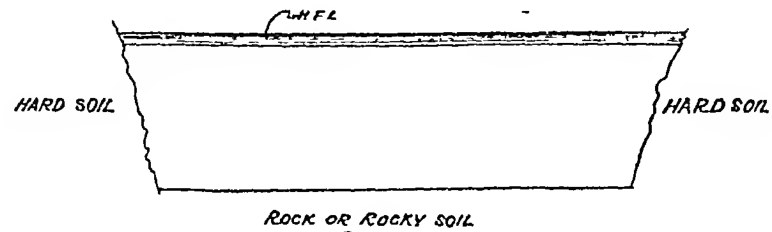

FIG. 1

IDEAL SITE FOR A CAUSEWAY.

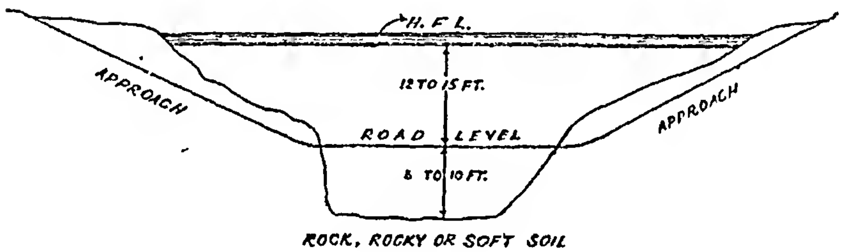

FIG. 2

IDEAL SITE FOR A HARD PASSAGE

BUT UNSUITABLE FOR A CAUSEWAY OR A BRIDGE

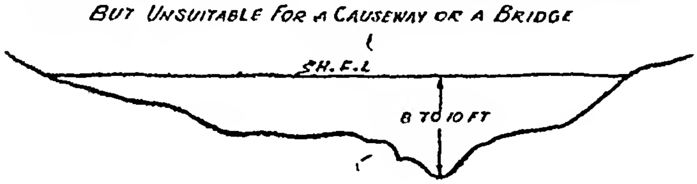

FIG. 3

11. It has already been stated that the design of a causeway or a submersible bridge calls for no special consideration other than that required for an insubmersible structure so long as the foundations rest upon rock or are encased in an incrodible soil. There are three ways in which the foundations of a causeway resting upon sand, clay, or loamy soil can get disturbed :—

(a) by percolation or piping.

(b) by scour or erosion.

(c) by loading beyond the bearing capacity of the soil.

12. The sands met with on the Deccan Platcau or in hilly tracts are coarse in structure. Therefore the piping action is out of question. The percolation through the clayey and loamy soils is never too strong to wash off the colloidal matter to affect the texture and density of the soil. Therefore in the design for the foundations, this consideration can also be ignored altogether.

13. The free vortex caused by the ventage water and the rollers formed by the overtopping water are the sources of scour and erosion on the down stream of the structure. If a bed of hard and inerodible materials is formed to resist the scour and is sufficiently extensive to accommodate the fury of the primary rollers, no forces can set in to disrupt the foundation soil however friable it may be.

14. The ascertaining of the bearing capacity of the soil and limiting the super-imposed load to it with the additional care that the load is uniformly distributed throughout, fully guarantees a state of static balance.

15. These considerations have given rise to the conception of Monolithic Base for foundations. This principle has been known to the practising engineers and has been resorted to by them, in its varying degree of development, in hydraulic structures but not with the full understanding of it. In a skeleton form it is as follows:—

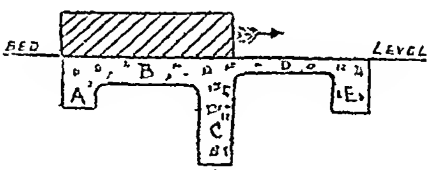

FIG 4

16. The entire substructure is in surkhi concrete and monolithic in construction. The function of *A* is to counteract the penetrating effect of the current and to safeguard any disturbance of the soil under *B*. *B* is the base for the superstructure. By regulating its thickness, the resulting intensity of pressure upon the soil can be governed. *C* is a deep retaining wall which boxes the foundation soil and acts as a cut-off in case of a break—through the apron. *D* is an apron to resist the disruptive action of vortices and primary rollers and *E* is the curtain wall to anchor down the apron and to resist the retrogressive action of secondary rollers. The only part of this substructure that needs to be carefully designed is the base to accommodate the superstructure. The point involved in it is to determine its thickness and this entirely depends upon the angle of dispersion

of pressure of the material used and the extent of super-imposed load upon it. There has not been, hitherto, research on lime and surkhi mortars and lime and surkhi concretes of various degrees of richness with different kinds of stone, brick and clinker ballasts to determine if any relationship exists between tensile, compressive, and shear stresses, acting independently or together, and the safe Modulus of Rupture for the material. Since lime and surkhi mortar is the cheapest binding material in India,—there are parts where lime stone of the highest possible quality is available,—there is hardly any reason why the scope for its utilisation should not be widened; but this is possible only when all its inherent properties are known. Until such time as this is achieved, there is no alternative but to resort to assumptions. Therefore the safe Modulus of Rupture for Coursed Rubble stone and concrete in surkhi mortar has been assumed as 20 lbs. per sq. inch and this gives the angle of dispersion of pressure as 49 degrees and 25 minutes but for ease of working, this angle has been assumed as 45 degrees.

17. With this data on hand, by a process of trial and error, the span is adjusted in a manner that the live and dead loads exert an intensity of pressure of $\frac{3}{4}$ to 1 Ton per Sq. Ft. upon the soil, the load being so distributed that the entire raft, without any pocket, acts under compression*. In Fig. 4, *A*, *C* and *E* follow the empirical rule and *D* is made wide enough to accommodate the rush of the primary water rollers. By experiments and observation, it is established that for a depth of flow of 12 to 15 ft. above the roadway, an apron width of 20 ft. is quite effective.

18. On this basis, designs have been evolved for causeways with arches and R.C.C. Slab decking and monolithic substructures. Typical designs are shown in drawings Nos. 1 and 2. The above two designs call for the use of relatively expensive materials and workmanship.

19. A cheaper design has been evolved by substituting pipes for the ventage. These pipes can be either premoulded or cast *in situ*. The premoulded pipes with the proprietary rights are expensive, but they have the advantage of expert supervision resulting in uniform quality, and are more convenient for use if the ventage is 2 ft. or less in diameter. Pipes moulded *in situ* can be done in surkhi concrete (Drawing No. 3), with the following advantages :—

(*a*) Cheapness in cost.

(*b*) Utilisation of local materials.

(*c*) Minimum skilled labour.

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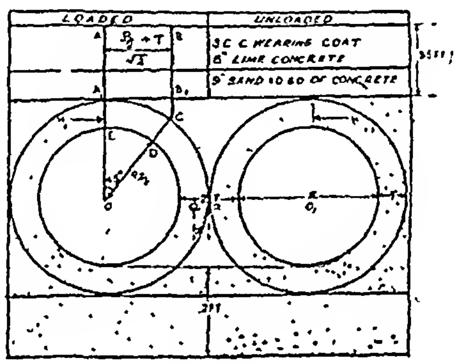
* For the details of design of compression Raft Foundations for culverts, please refer to Indian Concrete Journal for August 1944.

(*d*) Reduction in volume of materials required.

(*e*) A monolithic structure.

Surkhi concrete pipe causeways, 4 and 5 ft. in diameter with Monolithic Base Foundations have been designed and constructed and they have proved to be a complete success, both technically and economically. They are eminently useful when building stone is scarce or expensive.

20. Since the design of Surkhi concrete pipes does not cover the routine of an engineer, I shall briefly state the outlines of computations to arrive at the sizes of the members composing the structure.



Fig

Assumptions :—

(i) Safe bearing pressure of soil or sand. = n Tons per sq. ft.

(ii) Permissible compressive stress in surkhi concrete = F Tons per sq. ft.

(iii) Loading as per I.R.C. Standard :—

(a) Due to distributed load $= \dfrac{1523}{L}$ lbs. per sq. ft.

(b) Due to knife edge load reduced to Distributed Load $= \dfrac{2688}{L}$ lbs. per sq. ft.

(c) Total Distributed Load with 50 per cent. impact $= \dfrac{6316}{L}$ lbs. per sq. ft.

(d) L = Effective span in feet $= R + T$

upper half of the pipe is treated as a semi-circular and the lower one as an inverted arch.

pandrel filling in surkhi concrete is considered as a of arch ring.

ushion over the pipe consists of :—

ches of sand = 0.6 ft. of concrete.

ches of Lime concrete.

ches of cement concrete wearing coat.

iameter of Pipe.

hickness of Arch Ring.

Horizontal Thrust for the loaded arch.

" " " " unloaded arch.

The point of application of the Thrust is assumed acting horizontally at the centre of arch ring and at the crown.

Live load on half the quadrant, from the centre of arch.

Dead Load " " "

= Live load on full quadrant of the arch.

= Dead Load. " " " "

he middle point at the springing.

= X = The distance in feet at which the resultant acts.

ght of surkhi concrete = 140 lbs. per cu. ft.

The conditions to be fulfilled are :—

(a) that the thickness of the arch at the crown is adequate to resist the permissible compressive stress of the surkhi concrete.

(b) that the resultant lies within the middle third of the thickness of the arch rings at the springing.

(c) that the compressive stress at the junction of the two springings does not exceed the permissible compressive stress for surkhi concrete.

(d) that the intensity of pressure transmitted to the soil lies within the bearing capacity of the soil and is uniformly distributed.

21. Instead of taking up a specific case, a general case is worked out.

(a) *Stability of the Arch at crown*

$\frac{H_1}{T}$ should not exceed F

$$H_1 = W_L + W_D$$

$$= \frac{6316}{R+T} \times \frac{0{\cdot}5\,R+T}{\sqrt{2}} + 140 \times \text{area of } ABCDE \text{ (fig. 5.)}$$

$$= \frac{6316\,(0{\cdot}5\,R+T)}{\sqrt{2}\,(R+T)} + 140\left[\frac{0{\cdot}5\,R+T}{\sqrt{2}}\,(0.5\,R+T+1.35) - 0{\cdot}5\left(\frac{0{\cdot}5\,R+T}{\sqrt{2}}\right)^2 - 0{\cdot}125\pi\,(0{\cdot}25\,R^2)\right]$$

$$= \frac{6316\,(0{\cdot}5\,R+T)}{\sqrt{2}\,(R+T)} + 140\left[0{\cdot}95\,(0{\cdot}5\,R+T) + 0{\cdot}46\,(0{\cdot}5\,R+T)^2 - 0.1\,R^2\right]$$

$$= K_1 \text{ (say.)} \qquad \text{(i)}$$

Then $\frac{K_1}{T}$ should not exceed F.

(b) *Stability of the arch at springing.*

The unbalanced horizontal thrust = all the vertical forces.

Taking moments about Q. (Fig. 5.)

$$\frac{W_{L1}}{\sqrt{2}} \times \frac{R+T}{2} = W_{L1}\left(\frac{0{\cdot}5\ R+T}{2} + x\right) + 2\,W_{D1}\,x.$$

$$= W_{L1}\left(\frac{0{\cdot}5\ R+T}{2}\right) + W_{L1}\,x + 2W_{D1}\,x.$$

$$\therefore\ x = \frac{W_{L1}\left[\dfrac{0{\cdot}5\ R+T}{2} - \dfrac{R+T}{2\sqrt{2}}\right]}{W_{L1} + 2W_{D1}}$$

$$= \frac{0{\cdot}15\ T - 0{\cdot}1\ R}{1 + 2\dfrac{W_{D1}}{W_{L1}}},\ \left\{\begin{array}{l}\text{which should not exceed\_\_\_\_\_\_ (ii)}\\ \dfrac{2\ T}{6},\ \text{no tension is to be developed.}\end{array}\right.$$

(c) *Adequacy of section at springing.*

The intensity of pressure at springing should not exceed F.

Total pressure $= 2W_{L1} + 2W_{D1}$

$$= \frac{6316\ (R+2\ T)}{R+T} + 140\left[1{\cdot}35\ (R+2T) + (R+2T)\ (0{\cdot}5R+T) - 0{\cdot}125\pi R^2\right]$$

$$= \frac{6316\ (R+2T)}{R+T} + 189\ (R+2T) + 140\ (R+2T)\ (0{\cdot}5\ R+T) - 55R^2$$

$= \text{Say } K_2$ ....(iii)

Then $\frac{K_2}{2T}$ should not exceed F.

(d) *Intensity of pressure transmitted to the foundation soil.*

This should not exceed n

Total load $P = 2W_{L1} + 2W_{D1}$

$$= \frac{6316\ (R+2T)}{R+T} + 140\ (R+2T)\ 1.35 + 140\ (R+2T)\ (R+T+2) - 0.25 \times 140 \times \pi R^2$$

$$= \frac{6316}{R+T}(R+2T) + 189\ (R+2T) + 140\ (R+2T)\ (R+T+2) - 110\ R^2$$

$$\text{Intensity of pressure} = \frac{P}{R+2T}$$

$$= \frac{6316}{R+T} + 189 + 140\ (R+T+2) - \frac{110R^2}{R+2T}$$

$= K_3$ (say) ....(iv).

K_3 should not exceed n.

22. To get the required intensity of pressure and its uniform distribution upon the foundation soil the spacing of pipes is carefully adjusted.

23. With the butting of pipes against each other and the thickness of the arch ring as 9 inches, which might be taken as the minimum to ensure sound work, the intensities obtained for pipes ranging from 3 ft. to 5 ft. in diameter work out as follows:—

Diameter of pipe in ft.	Intensity of pressure H^1/T at crown Tons per sq. ft. (Eqn. (i))	Eccentricity of resultant thrust at springing in ft. (Eqn. (ii))	Intensity of pressure at springing Tons per sq. ft. (Eqn. (iii))	Intensity of pressure on soil Tons per sq. ft. (Eqn. (iv))
3·00	1·90	0·13	2·78	1·10
3·50	1·90	0·16	2·81	1·02
4·00	1·91	0·18	2·85	0·95
4·50	1·91	0·20	2·91	0·91
5·00	1·95	0·22	2·96	0·87

By varying the thickness of the pipe, the diameter and the spacing, a number of combinations can be worked out to select the most economical and technically perfect design.

24. The 4 ft. and 5 ft. diameter pipe causeways give a gross height of 5½ ft. and 6½ ft. above the average bed level. These road levels will be found to answer effectively the cases met with in general.

25. Practical experience has also indicated that 4ft. and 5ft. pipes are easy to build and economical. As already stated, the entire structure can be constructed in mass surkhi concrete doing away with the use of building stone and skilled workmanship. The sceptic may object to the use of concrete for face work and entrench himself behind the argument that it is unsuitable to cope with the concussions of floating debris. Such apprehensions can be met with by providing the outer lining in stone masonry and, if the cost is no consideration, the entire structure can be done in stone masonry. The only part of the structure that needs care and attention is the moulding of the pipe *in situ* and for this, steel centring has been designed (Drawing No. 4). The centring is semicircular, collapsible and in 7⅓ ft. lengths. The lower half of the pipe is cast first, the other half is set up and adjusted to mould the upper half. With three sets of these centrings, the work can continue unhampered and without a break.

26. The relative cost at pre-war rates for the perforated parts of the three types of constructions shown on the Drawings at Hyderabad City rates works out as follows :— (all costs in Hyderabad Sicca Rupees)*

	Types	*Cost*
(i)	8 ft. Segmental Arches with superstructure in stone masonry 6 ft. in height and Monolithic Base.	Rs. 105/- per R ft. or Rs. 18/12/- per sq. ft. of waterway.
(ii)	4 ft. R. C. C. Slab with superstructure in stone masonry 2 ft. in height with Monolithic Base.	Rs. 73/5/4 per R ft. or Rs. 55/- per sq. ft. of waterway.
(iii)	4 ft. Diameter surkhi concrete pipe with Monolithic Base.	Rs. 72/11/8 per R ft. or Rs.31/11/1 per sq. ft. of waterway.
(iv)	5 ft. Diameter surkhi concrete pipe with Monolithic Base.	Rs. 80/- per R ft. or Rs. 21/9/3 per sq. ft. of waterway.
(v)	Approaches (common to all)	Rs. 18/12/10 per R ft.

No attempt is made to correlate these results except to show that on the basis of waterway, the lower the causeway in height the more expensive it is in unit cost.

27. Hitherto, the advantages concerning the causeways have been dealt with. The disadvantages at once appear in two distinct cases and they are the

(a) forest areas.

(b) silty streams.

28. The intensity and volume of floating debris is high in forest areas. As a rule, the ventage is too small to pass the debris with the result that it blocks the vents, converts the causeway into an anicut, and upsets the duration of utility of the causeway by traffic. To remedy this defect, a stockade was tried on the up stream side but it was found to be ineffective as it tended to silt up the bed, and

in other respects, merely changed the scene of action little higher up. Therefore, if causeways are to be built at all in forest areas they should be sufficiently low to pass floating debris over them. Thus, the duration of service does suffer but the nuisance of keeping the ventage clear and the possible damage to the structure is obviated.

29. The silt-charged streams deposit heavy accumulations of silt particularly on the approaches where the flow is retarded or is, more or less, quiescent. The greater the depth of water the thicker is the deposit. There are no means of preventing it, but it can be minimised by raising the road level so that the approaches may lie at a higher level where the depth of water is low and the duration of submergence small.

The ideal solution for such sites is an insubmersible bridge with large spans.

30. This paper is no more than a plea to standardise the basis of design for causeways and to popularise their adoption which has been very restricted hitherto although the Tropical and Semi-tropical countries afford an ideal field. The conference of Chief Engineers of Provinces and States held at Nagpur from the 15th to 18th December 1943 has recommended the use of causeways provided the effective submergence at a time does not exceed 12 hours and the frequency is not more than 6 times in a year. The tolerance prescribed is generous and should be a source of encouragement to widespread adoption of this type of structure.

31. The obvious conclusions to be drawn from this paper are as follows :—

(a) so long as a causeway is founded on rock or its foundations are well encased in an incredible substratum of soil, the design of super and substructure calls for no considerations other than those required for an insubmersible structure.

(b) the entire length of the causeway proper should be perforated and the spacing between the vents should not exceed 3 ft. to avoid still water regions, and the consequent action of free vortices.

(c) the road level of the causeways should be fixed with reference to the configuration of the banks and not for a pre-conceived discharge from the catchment.

(d) the flanks should be well studded into the banks to counteract the outflanking action by the current.

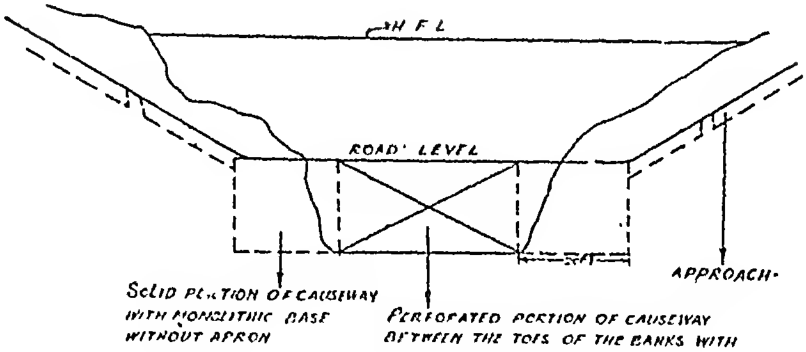


FIG. 6

(e) the approaches should run below the natural ground level and be provided with efficient side drains and revetted banks, if the soil is loose. Cement concrete surfacing is an advantage as it is proof against soddening and resists the play of water.

(f) erodible soils such as sand, loam and clay afford just as effective foundation provided they are protected from the disturbing action of flowing water. The Monolithic Base is a device which needs to be carefully designed with respect to the super-imposed load, the bearing capacity of the soil, and the depth of the overtopping water.

(g) just as causeways on hard soils can be constructed skew, so also causeways on soft soils can be constructed skew with Monolithic Bases. In such a contingency, to avoid expense, the use of Stone Arches should be replaced by surkhi concrete arches. Surkhi concrete pipes are eminently amenable to this treatment.

(h) with the evolving of Monolithic Base, the question of securing hard soil for the foundations is set aside and with it the inevitable kinks and curves along the approach roads should disappear.

(i) the surkhi-concrete-pipe-causeway utilises the minimum amount of materials and skilled labour. This form of construction which is fully monolithic ought to find a universal application. In course of time, mere barrels, piercing embankments, should also replace the conventional type of culverts.

32. The appended statement gives the details of the causeways constructed in H.E.H. the Nizam's Dominions during the last few years on the technique of Monolithic Base Foundation.

INDIAN ROADS CONGRESS

PAPER NO. IX—101. 1944.

"A DESIGN FOR BULLOCK-CART WHEELS"

By B.V. Vagh, B.E., M.I.E. (Ind.),
Manager, Bitumen Department, Burma Shell Co., Ltd., Bombay.

CONTENTS.

SYNOPSIS.

(1) The author discusses the results of an investigation into the requirements of the main types of bullock-carts in India arising out of a suggestion made by him at the Gwalior Session of the Indian Roads Congress in 1943 for the improvement of the Spoke*—type wheel. The investigation relates to the improvement of the Spoke and Arm types, provision of improved bearings and springs, costs of construction and maintenance, financial aspects of the improvements, and the author's approach to the problem. By comparison with various alternative designs the author suggests that the most suitable design should.

(i) make use of existing materials of construction and workmanship,

(ii) cause least disturbance to the village wheelwright industry,

(iii) be based on the experience of present designs, and

(iv) be available at a cost not very different from that of present construction.

*I.R.C. Proceedings, Vol. VIII "Improving the Road Rupee Ratio by W. L. Murrell, O.B.E., in which Mr. Murrell divides bullock [illegible] els into two broad classes, the Spoke type and the Arm type, [illegible] red to as [illegible] type and [illegible] type wheels.

(2) In order to be effective from the point of view of causing least damage to roads, the main requirement of a cart wheel is a broad tyre. This means more maintenance, which has to be provided for by increasing hire-charges of carts by law. It is estimated (on figures produced by the author), this increase is about 1 [illegible] per cent above present earnings from hire. If maintenance is met out of increased hire-charges, the cost of renewing broad-tyre wheels (when they become old) is not materially more than that of existing types. Hence if the State pays for initial conversion, cart-owners would be able to look after both maintenance and renewals.

(3) *Conversion to pneumatic tyres of urban carts numbering about 10 per cent. of the cart-population and to broad-rimmed tyres of rural carts numbering about 90 per cent. is suggested.*

(4) The cost of this conversion is estimated at Rs. 11·25 crores which is sufficiently low to be practicable. Alternatively the State should supply, free of cost, tyres to all carts, both for new construction and maintenance. The cost of this proposal for steel tyres is only about 8 per cent. of the road-maintenance bill.

(5) The proposal has other advantages also and would obviate legislation for minimum hire-charges. Conversion should form part of the Road Plan of the Chief Engineers' Conference and be carried out simultaneously with that plan during next 20 years, as and when the present wheels become due for renewal.

I. INTRODUCTION.

(a) Genesis.

1. At the Gwalior Session of the Indian Roads Congress, during the discussion on Mr. Murrell's paper on "Raising the Road-Rupee Ratio with special reference to the steel tyres", the author made a suggestion for the improvement of the wheel of an *S*-type Bullock cart. A pair of wheels was made to this design and the results obtained from it, and the modifications indicated by their use on the road, were placed before the Bullock-cart Sub-Committee of the Council of the Indian Roads Congress in Bombay in March 1944. The Sub-Committee asked the author to make one more pair of wheels incorporating certain further modifications and minuted as follows:—

> "Mr. Vagh should be requested to report on the two pairs of wheels made by him for the *S*-type by furnishing also the specifications with a view to circulating the results to the Provinces and States".

2. On the question of improving wheels of bullock-carts the Council of the Indian Roads Congress minuted as follows at their meeting at Gwalior in October 1943:—

> "It was also agreed that further experiments should include investigation of the possibility of improving the bearings of the wheels not only to reduce the destructive effect of the wheel but also to increase the pay-load of the cart".

(b) Aims.

3. This Paper discusses the results of an investigation into both the above suggestions and the possibility of evolving a design for use on both the *S* and *A* types of wheel. It discusses two Designs.

(i) *Without* roller or ball bearings and/or springs, and

(ii) *With* them.

Both these designs make use of materials and methods of construction employed at present by village wheel-wrights in the construction of wheels without, in any way, disturbing their industry.

4. The designs aim at the reduction of load transmitted to a road surface, from about 667 lbs. per inch width of tyre in present construction to about 300 lbs. in (i) and 240 lbs. in (ii), the figures being based on load per wheel in a standard bullock-cart in the City of Bombay.

(c) **Chapters.**

5. The Paper has been divided into five parts,

(i) Main types of bullock-cart wheels in India and their requirements,

(ii) A design for wheel for use in existing bullock-carts *without* improved bearings and/or springs,

(iii) A design for wheel for use in existing bullock-carts *with* improved bearings and/or springs,

(iv) Financial aspects, if the designs proposed in the Paper are found practicable and are adopted and,

(v) A Summary of conclusions.

There are two appendices, and seven drawings.

II. MAIN TYPES OF BULLOCK-CART WHEELS IN INDIA AND THEIR REQUIREMENTS.

(a) **Arm type and Spoke type wheels.**

6. The two common types of two wheeled bullock-carts in this country are the *A*-type and the "*S*-type ("*A*" standing for "Arm" and "*S*" for "Spoke"). The wheels of 4-wheeled carts are generally of the *S*-type. The *A*-type has a broad wooden tyre; the *S*-type a narrow steel tyre. The *A*-type is understood to preponderate in alluvial and or sandy tracts where the soil requires a broad tyre and the *S*-type in tracts having metalled roads which can stand a narrow tyre.

7. It is likely that the widths of tyres required by these two types of carts have influenced the construction of wheels employed therein. A broad tyre would be expensive if steel were used in its construction; hence a wooden tyre has to be used in an *A*-wheel, and to fix it securely, without a shrunken, steel tyre, one-piece spokes (arms) have to be driven through the hub and through one another to stabilise the assembly. On the other hand, steel can be employed in the construction of a narrow tyre in an *S*-wheel and a shrunken steel tyre is sufficiently strong to impart stability to the assembly of a wheel. Hence arms need not be used in its construction. Half length spokes can be notched into the hub at one end and the felloe at the other, instead of being driven through the hub as in the other type.

8. On the present designs employed in the Bombay Presidency, an *A*-wheel is heavier and requires more tractive effort than an

S-wheel. The wooden tyre of an *A*-wheel is also more expensive to maintain than the steel tyre of an *S*-wheel. Within limits the same should be true of these two types in other Provinces also. In that case it may be surmised that as a rule an *S*-wheel is lighter and cheaper than the other type. Therefore, if an *S*-wheel could be designed with a sufficiently broad felloe for use in tracts where the *A*-wheel is employed within about the same cost as at present, it should be possible to eliminate the *A*-type and to adopt the lighter *S*-type in its place. This fact may have some bearing on the transport problems of tracts employing the *A*-type at present.

9. The damage caused to road surfaces by the narrow tyre of an *S*-type can be minimised if the tyre can be broadened without using more steel than at present and without losing the main advantage of a shrunken iron tyre in lightening the construction of a wheel.

10. The problem would thus appear to be two-fold:—

(i) to eliminate the heavy *A*-wheel, and

(ii) to minimise the damaging effects of the *S*-wheel.

The designs discussed in this Paper are intended to meet both these requirements.

11. The *A*-type wheel sometimes uses a steel tyre in its construction to protect its wooden tyre against wear and tear when using water-bound macadam roads regularly. Conversion of such wheels to new wooden tyres does not solve the problem. Such a wheel requires either an all-steel or a composite tyre, consisting partly of steel and partly of wood, to save maintenance on their tyres. This requirement also is met with in the designs discussed in this Paper.

III A DESIGN FOR WHEEL FOR USE IN EXISTING BULLOCK-CARTS WITHOUT IMPROVED BEARING AND/OR SPRINGS

(a) Basis for discussion.

12. The basis on which the proposed designs are offered for discussion is that they relate primarily to the *S*-wheel but at the same time can be employed in the existing *A*-wheel with the ultimate object that the *A*-wheel will be replaced by the *S*-wheel when the cart-owner sees the advantage of the proposed design.

13. A design for the improvement of an *S*-wheel has, in the

opinion of the author, to be based on the fact that *it is not possible to eliminate a steel tyre of a certain thickness from its construction.* The suggestion made by the author at the Gwalior Session of the Indian Roads Congress during discussion on Mr. Murrell's Paper was based on this fact.

(b) **Bombay Bullock-Cart : S-wheel.**

14. Particulars of a bullock-cart employing an *S*-wheel are given in plate I, and Table I. These relate to a Standard bullock-cart in the city of Bombay which is fairly representative of the types in other parts of the Presidency. The suggestions made in this Paper for improvements of the wheel will, therefore, suit the other types with minor modifications.

15. The body is generally made from unseasoned wood which is very susceptible to temperature effects of swelling and shrinking and hence *the use of bolts and nuts in its construction is ruled out.*

16. The felloe and spokes are made from country teak weighing about 46 lbs. per cu. ft. and the hub from *Khair* wood weighing 65 lbs. per cu. ft. The country teak is less tough and more susceptible to expansion and contraction but it is preferred on account of its lightness, which keeps down the weight of the wheel. Any modification of the wheel should tend to keep the weight as low as possible.

17. Due to alternate swelling and shrinking of the unseasoned felloe in wet and dry conditions, the steel tyre shows signs of getting loose after each monsoon. The tyre is then removed, shortened slightly, and refixed to the felloe after the felloe has been shaved about 1/8 inch to remove the charred wood formed at the previous fixing of the red-hot steel tyre. The thickness of the felloe will thus be reduced by about one inch, by this process, in a period of seven years, which is about the average life of a 5/8 in. steel tyre.

18. Minimum depth of felloe for stability is 3 in. With an average reduction of 1 in. depth, every 7 years, and an initial depth of 6½ in., a felloe would last for about 25 years requiring 2½ replacements of the steel tyre. In actual practice, due to alternate expansion and contraction, disintegration by rain, and continual use, joints in the assembly become loose, and a wheel has generally to be replaced once every 15 years, requiring normally only one renewal of the steel tyres, and reducing the depth of felloe to 4½ in.

19. Figures 1 (*a*) to 1 (*d*) indicate different possibilities of

increasing the width of felloe of the existing S-type wheel without unduly increasing the weight of the steel tyre.

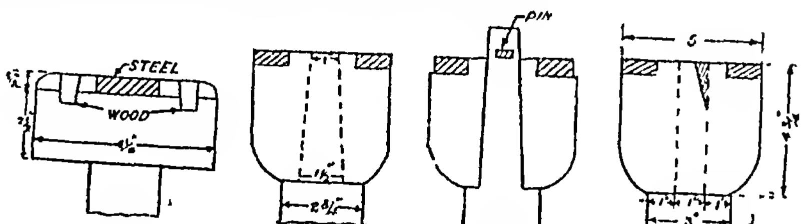


FIG 1(a) FIG 1(b) FIG 1(c) FIG. 1(d)

(*i*) In Fig. 1 (*a*) the present felloe is turned sideways with the broader face in contact with the road surface, with steel tyre superimposed in the centre and ends filled with wood.

A pair of wheels made to this design in Bombay showed that the wooden strips gave way rapidly, due to the disintegration of the grains of the strips parallel to the line of travel of the wheel, and it was impossible to have long wooden strips required by the long sections of such a wheel without their grains being parallel to the sections. Also the strips were too thin and had no lateral support on one side.

(*ii*) Fig. 1 (*b*) shows a wide felloe with steel strips on either end, with part of the wooden felloe in the centre. The central strip forms part of the felloe instead of being superimposed, so that resistance to disintegration extends over a greater depth. The central strip has in addition lateral support. The difficulty in constructing this type is to prevent the felloe from tilting when the tyres are being fixed. A special clamp or tool to hold the felloe in position would add to the cost.

(*iii*) Figs. 1 (*c*) and 1 (*d*) show the arrangements made to overcome the tilting of the felloe when fixing the steel tyres. In fig. 1 (*c*) the spokes are projected beyond the felloe and held in position by pins to hold the felloe tightly while the tyres are being fixed. The projections are then cut off. One pair of wheels to this specification had been manufactured at Bombay. Details are shown in Plate II.

(*iv*) In Fig. 1 (*d*), the felloe is held in position by wedging the spokes in the felloe, thereby checking the tilting tendency of the wheel by the resistance of the wedge. A pair of wheels has been made at Madras to this specification.

(*v*) A suggestion has been made to have the felloe in two parts as indicated in Fig. 2, the lower part being cut as usual with grains parallel to the sections of the wheel, and the upper part consisting of a number of blocks of wood cut transversely with the grains transverse to the line of travel. This necessitates a clamp which has to be avoided. Secondly, the arrangement may prove difficult in practice. During dry weather the felloe shrinks and the steel tyre shows signs of getting loose. There is always a time lag between this and the refitting of the tyre; and a two-piece felloe may prove more difficult than one-piece one, in this time lag. Also, the advantage of transverse grains may not be appreciable in this construction as the depth of the top piece is only $1\frac{1}{2}$ in. against $4\frac{1}{8}$ in. in the type shown in Fig. 1 (*c*).

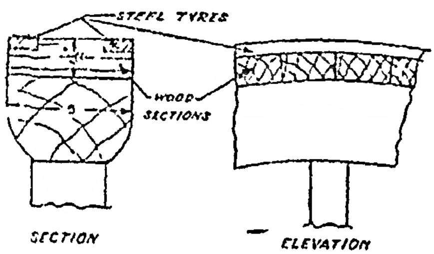


FIG 2

20. If the felloe is to be widened without eliminating a steel tyre, the type shown in fig. 1 (*c*) and in Pl. II appears to be the most suitable, taking into consideration the optimum width, depth, and section of felloe and steel tyre, effect of felloe on spokes and hub, weight and diameter of wheel, and the tractive effort. Particulars of the existing wheel and the improved wheel (with two steel tyres and a central wood strip) are given in table I, and details of the arrangements are shown in plates I and II.

21. Experience in the manufacture of two pairs of wheels to this design has indicated that it is not desirable to leave any margin on the felloe outside the steel tyres. This is because the operation of fixing tyres has to be completed in the shortest possible time and, therefore, it is best to leave on the felloe the exact space required by tyres. The width should, therefore, be 5 in. instead of $5\frac{1}{4}$ in. as shown in the drawing. Secondly, the Madras expedient of wedging spokes allows more bearing space for the fellow, being 7/8 in. against 5/8 in. shown in the drawing. It is felt that it would be better still to widen this space to 1 in. by increasing the width at the base to 3 from $2\frac{3}{4}$. Finally, it would be

useful to increase the depth of the felloe 1/8 in. to allow more margin for maintenance. The section would, therefore, be as indicated in fig. 1 (*d*).

For this section, item 2 in Table I will be 41/4 in. and item 6, 46 in., other particulars being the same. Cost of construction has been based on this section.

22. Comparative costs of construction and maintenance of one wheel to the existing type (plate I) and proposed (plate II) are given in the Table II.

23. The proposal to use 3 steel bands in the new design, (two tyres ½ in. thick at ends and one band 3/16 in. thick in the centre), suggests a more simple alternative of providing one band of uniform thickness for the entire width of the felloe. For a 5 in. width of felloe, the thickness of the band has to be reduced to about 5/16 in. if the weight of the band is to be kept the same. This is the minimum required for stability. With an additional 1/8 in. for wear and tear, the minimum thickness has to be 7/16 in. or say ½ in. and to keep to the same weight of wheel, the width of the felloe has to be reduced to 4 in. The weight of the steel tyre (80 lbs.) exceeds the weight of the wood in the felloe (58 lbs.) and this is not desirable as the heavier steel tyre may tend to slip off the wooden felloe. A steel surface is never likely to be true when it is finished by hand. Therefore the distribution of load a over 5 in. wide steel tyre made of 3 bands would be at a number of points and not over the full width uniformly. Also the 3 bands may not be made to the same diameters, preventing contact of the full width of the tyre with the road surface. Hence this proposal is not practicable unless the tyres are produced by machine to standard dimensions.

24. If a 3/8 in. steel tyre is used for the full width, the margin of 1/16 in. over the minimum required for stability will provide for fair wear and tear for a period of three years only, against 7 years assumed, and the annual maintenance charges at pre-war rates will be Rs. 4/2/- against Rs. 2/13/- in the proposal, [(Table II. b (2)]. This alternative may not also be desirable.

25. Maintenance of the wooden part in the proposed design is an unknown factor. Except on water-bound macadam roads, wood is not likely to fare badly, but wear and tear on it will be more than on steel, and some method of maintaining it suitably has to be found. The steel band has been considered above. Other substitutes that may be considered are, rubber sheeting, impregnated coir-matting, plastics, and wood preservatives.

26. **Rubber Sheeting.**—Several times in the past a suggestion

has been made that solid rubber tyre should be adopted for a cart wheel as is done in a tonga wheel. Mr. Murrell has pointed out that the cost of rubber required to meet this suggestion would be prohibitive. A rubber tyre may, however, be considered. The tyre may be used (i) either like the rubber band of a tonga wheel to take up the entire load on the wheel or (ii) as a protective covering to the wooden part of the proposed felloe like the 3/16 in. steel band referred to above.

27. In the former case the construction would be somewhat as shewn in the sketch (Fig. 3). In this construction the steel tyres will not touch the road surface; hence they need not be more than 5/16 in. thick. The rubber tyre, which will take up the wear and tear should have to protrude at least 5/8 in. and its total thickness would be about 1 $\frac{1}{4}$ in. At the pre-war cost of a 5/8 in. rubber tyre of a bullock-cart equipment, the cost of tyre required in this construction would be about Rs16/- and the saving on steel by using 5/16 in. instead of $2\frac{1}{2}$ in. thickness would be Rs 2/-. Therefore, on the assumption that a rubber tyre of this section is available, the cost per wheel would be Rs,14/--

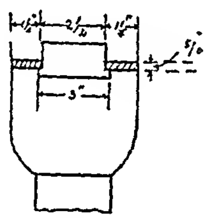


FIG 3

28. The width of a standard bullock-cart pneumatic rubber tyre of the same thickness is about $4\frac{3}{4}$ in. and it has an average life of about 5 years. In the present case the width is only $2\frac{1}{2}$ in ; hence it will be subject to at least about twice the load as on the other tyre and, therefore may not last for more than about $2\frac{1}{2}$ years In that case the maintenance would be Rs. 14 x 2/5 = Rs. 5/10, say Rs. 6/- per annum. Including the maintenance on the two steel tyres the *total would be Rs. 8/- per wheel per annum.* Retreading, if feasible on a section of this width, may reduce this cost. At pre war price a solid rubber tyre of the type employed in tongas but made to the above design would cost about the same as a rubber tyre of the same design. It would, however, add 19 lbs. to the weight of the wheel against 9 lbs. in the case of a steel tyre and 18 lbs. in the case of 3/16 in. steel band

29. In the second suggestion a 1/4 in. rubber tyre is superimposed

on the wooden part like the steel tyre referred to earlier. About 1/8 in. of this tyre will have to be recessed in the wood and the remaining 1/8 in. will take up the wear and tear. The pre-war cost of such a band would be about Rs. 3/9/-. The width of felloe in the proposed design being about the same as in a standard pneumatic tyre for a bullock-cart, the wear in the two cases may be the same. This is about 1/8 in. per annum in the former. Therefore, the proposed band also may last for a year. The maintenance thus would be Rs. 3/9/- for the wooden part plus Rs. 2/- for the steel part i.e. *Rs. 5/9/- per wheel per annum.* Assumptions of the life of these tyres are based on the performance of a pneumatic tyre in the absence of other data. However, since in the present case the tyres are not pneumatic, these assumptions would be on low side and the actual maintenance would be more than shown.

30. **Impregnated coir matting.** Coir matting is likely to be available at many places in India and is used in small strips for yoking bullocks to carts. It is cheaper than rubber sheeting, and perhaps its wearing properties may be improved by impregnating it with bitumen. The present cost of coir matting required per wheel in this design is understood to be about As. 6/-. Its pre-war price may be about As. -/4/-. Maintenance on steel which is the cheapest method of maintenance so far is As. -/13/- per wheel per annum for the wooden portion. Therefore, assuming that the cost of impregnation is As. -/4/- and the total cost is As. -/8/- in all including matting, the method would be feasible if the matting lasts for about 8 months. This requires investigation. Similar data may be collected on strips of impregnated tarpaulins, jute, gunny or felts all of which are likely to be useful provided they can be fixed to the felloe without difficulty.

31. **Plastics.** Here also no data is available. The suggestion is that the wooden part in the proposed felloe should be repaired from time to time as it is worn out, with a plastic specially prepared for the purpose. If the idea is found feasible the cart-driver himself would be able to attend to this work and the cost may not be heavy.

32. **Wood Preservatives.** Here the idea is to develop a cheap method of either impregnating or covering the wooden part of the felloe with a suitable material, which would toughen it so that its normal wear and tear is not more than the part required to be shaved for the steel portion i.e. about 1/8 in. per annum. If this is feasible the problem of maintenance should be simplified since the felloe has to be shaved off 1/8/- in every year to refix the steel tyres and, therefore, if its wooden portion also wears out to the same extent, its shaving would be saved.

33. **Summary.** Summarising, the position about maintenance in the proposed design would appear to be as follows:—

Material	Steel Section.	Wooden Section.	Total Cost per wheel.	Present cost.	Difference per wheel.	Difference per cart pre-war cost.	Difference per cart post-war cost @ 5 % more.
Steel	Rs 2/-	-/13/-	Rs. 2/13	Rs. 1/8	Rs. 1/5	Rs. 2/10	Rs. 4/-
Rubber tyre $2\frac{1}{2}'' \times 1\frac{1}{4}''$	Rs. 2/-	Rs. 6/-	Rs. 8/-	Rs. 1/8	Rs. 6/8	Rs. 13/-	Rs. 19/8
Rubber band $\frac{1}{4}'' \times 2\frac{1}{2}''$	Rs. 2/-	Rs. 3/9	Rs. 5/9	Rs 1/8	Rs. 4/1	Rs. 8/2	Rs. 12/3
Other Methods.	Rs. 2/-		Not	known			

Thus in the light of known data, steel happens to be the cheapest method of maintaining wood. If the methods, about which no data is available, produce an equally economical formula, well and good. If they do not, then in terms of economy estimates have to be based on steel. The author has an open mind on this issue. A steel tyre has earned a bad name in India, but perhaps that is because it is too narrow, it has cutting edges and the wheel is subject to wobbling. All these defects may be minimised to a large extent in a wide section. In that case steel may not be so injurious to road surfaces as at present. On the other hand, steel is more rigid than any method of road construction and it is unfair to subject the latter to its action. In the ultimate analysis, economics cannot be ignored and, therefore, for estimating purposes the author is assuming figures of maintenance on the use of steel for the wooden portion.

(b) *A*—Type Wheel (Ahmedabad Type).

34. Particulars of a cart using an *A*-wheel of the type employed in the Gujrat district of the Bombay Presidency are enclosed in Plate III and other details are given in Table I. The felloe of the wheel of this cart consists of four sections. Two of them are fixed with dowels to one pair of arms, 4 in. × 2 in. and two are fixed to another pair $2\frac{1}{2}$ in. × $2\frac{1}{2}$ in. These arms are driven through the hub and through one another. The use of full length arms instead of spokes employed in the construction of an *S*-wheel, the method of driving them through one another and through the hub and, the long dowels employed in the periphery render this construction stable without the use of a shrunken steel tyre. No steel bands are used on the hub also. The axle-hole carries two small steel collars to prevent wear on wood.

35. The wooden tyre in this wheel suffers a great deal from wear, and as a rule the felloe has to be shaved about an inch every year to level its surface, giving an average life of 5 years, as by then the diameter of the wheel is reduced by 10 to 12 inches increasing the tracking effort to such an extent as to make it unsuitable for use. The annual maintenance cost is estimated to be Rs. 4/- for earth roads. Whenever such carts have to use regularly metalled roads, they employ a steel tyre 3 in. × 3/8 in. which is renewed every 4 years, with an annual maintenance cost of Rs. 2/5/- per wheel.

36. Thus an *A*-wheel which is smaller in diameter but 31 per cent. more heavy than an *S*-wheel, requires more tractive effort and is twice as expensive to maintain. It thus appears desirable to replace the *A*-type by an *S*-type wheel. The proposed *S*-type wheel lends itself for such a replacement (see Table 1).

37. The *A*-type wheel cart carries a much heavier load than the *S*-type cart, and hence the wheel when converted to *S*-type has to be stronger. This can be achieved in three ways :—

(i) by thickening the spokes,

(ii) by widening the hubs, and

(iii) by widening the base of the felloe and increasing its depth,

as shown in the final design, Fig. 2 Plate IV.

38. An interim design for the change over to the *S*-type is shown in fig. I plate IV and fig. 4 plate III (see also Table I). This can be adopted till such time as the local wheel-wrights, at the stations where *A*-type wheels are used, become conversant with the technique of conversion to the final design. Both these two types have the same weight and diameter. It is proposed to make one wheel of each of these two types, fit them to a cart, and test them under traffic.

39. The hub has been widened to house the new spokes, while the base of the felloe has been increased to 4 in. to fit in with the size of the spokes. The need for extra spokes in this arrangement is due to the fact that, as shown in Fig. 4, the unsupported chord length of the felloe in the proposed construction is 17 in. in place of 7 in. in present construction and 8 in. in an *S*-wheel. The hub has to be widened by 4 in. to house these spokes. This fact adds 19 lbs. to the weight of the wheel.

Therefore, the depth of the felloe cannot be increased as would be possible in the *S*-design discussed earlier.

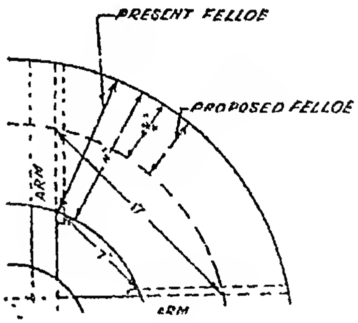


FIG 4

40. At their Lucknow meeting during September 1944 the Council of the Indian Roads Congress decided to send to the Provinces and important States standard designs for cart-wheels to enable them to manufacture one pair of wheels each and to report results to the Bullock-Cart Sub-committee after six months. Accordingly the two designs discussed in this paper have been sent to them, *viz*. one of the Bombay wheel which is suitable for a load of upto 2500 lbs. and the other of the Ahmedabad wheel which is suitable for a load of upto 5000 lbs. In both designs a 3/16 in. thick steel band has been suggested in the centre of the felloe in addition to two $1\frac{1}{4}$ in. by $\frac{1}{2}$ in. tyres and both have the same weight as in present construction.

(c) T-Section V/s Rectangular Section.

41. For these *A*-wheels which employ a steel tyre when using metalled roads, Mr. Murrell has suggested a *T*-Section 6 in. wide and 3 in. deep with a 2-in. leg for bolts and flats. For the *A*-wheel discussed above, this design would be lighter than the design in the present construction, and would, therefore, be an improvement, but it would add to the maintenance. According to present experience about an inch has to be shaved off the felloe every year. This would mean that the proposed depth of 3 in. would last for 3 years. In practice the last inch of this section is not likely to be useful for bearing the load on the cart and, therefore, the felloe will have to be replaced practically after two shavings in two years. This will double the cost of maintenance. Another point is the use of bolts and nuts which a

would

T-section entails. From the author's point of view it has two defects :—

(i) the fact that the wood used in this construction is unseasoned, exposed to wet and dry weather at all times and, therefore, liable to expansion and contraction ; and finally, that the felloe is subjected to continual jerks in travelling, may tend to widen the bolt-holes, thus preventing a tight fit and throwing more strain on the bolts, and

(ii) the nuts may require frequent attention which a normal cart-driver may not always be inclined to pay.

(d) Alternative designs.

42. For comparison with the composite tyre suggested in the design discussed above, the author prepared three others, one with a wooden tyre, one with steel, and one with a rubber tyre stuffed with chopped hay. The last named two, and eight other designs collected from the proceedings of the Indian Roads Congress have been given in Plate V. These eleven designs and the Cumming wheel and its wooden substitute have been discussed in Appendix A.

(e) *Structural Stability of the Proposed Design.*

43. At the author's request and through the good offices of the Government of Bombay, Professor Taraporevala, Professor of structural Engineering, in the College of Engineering, Poona, has prepared a note on the structural stability of the present and proposed designs. (see Appendix B.)

IV. A DESIGN FOR WHEEL FOR USE IN EXISTING BULLOCK CARTS WITH IMPROVED BEARINGS AND/OR SPRINGS.

(a) Improved Bearings.

44. In para 2 of this Paper a reference has been made to the provision of improved bearings in bullock-carts. This point was raised at the Gwalior meeting of the Council of the Indian Roads Congress.

The use of roller or ball bearings in a cart-wheel would reduce tractive effort, prevent its wobbling and increase the pay-load. The last-named point may necessitate a new design for a cart. For the present the author would confine himself to the wheel and see how far it is possible to adopt roller-bearings in its present construction without involving changes which may be beyond the understanding of a wheel-wright.

(b) Broad-based felloe with improved bearings.

45. Plate VI shows such a design and how it can be fitted inside the present hub of an *S*-wheel. The design makes use of the roller-bearings employed in a standard pneumatic tyre equipment of a bullock-cart. It will be seen that it can be very easily fitted inside the present hub. The only changes are:—

(i) a $3\frac{1}{2}$in. tapered collar for the bearing,

(ii) a hexagonal nut and split pin to hold it tightly,

(iii) a mild steel collar welded to the shaft to prevent the wheel from wobbling,

(iv) the cutting of a $1\text{-}\frac{1}{8}$ in. portion on each side of the hub, which is unnecessary in this design, and

(v) an extension of the wooden axle-box by $1\frac{1}{2}$ in. necessitated by these changes. The cost of these changes at pre-war prices would be at least Rs. 20/- per wheel. Although this design relates to the hub of a Bombay wheel it can be adapted to the hubs of other *S*-wheels, which are built on the same basic principle, with a few minor changes in constructional details.

46. It is possible to take advantage of reduced tractive effort offered by improved bearings to reduce the diameter of the wheel and, with the same weight of the wheel as at present, to widen the felloes still further to obtain a further reduction in the load transmitted to a road surface.

47. Plate VII shows such an arrangement. The wheel diameter has been reduced to 3 feet, (which the author considers should be the minimum for a cart), and the width of the felloe has been increased to $6\frac{1}{4}$ in. all the methods of construction being the same as in design discussed earlier. The cost of this wheel at pre-war prices is the same as in present construction, i. e. Rs. 26 in Bombay and its weight is 201 lbs. with three steel tyres-against 209 lbs. in the present construction. The load distribution is also less. (See Table I)

(c) Springs.

48. The provision of roller-bearings would raise the question of springing and, if the cost of springs and that of bearings prove prohibitive, the question of providing one or the other has to be considered. Opinion does not seem to be definite on this point and it is a matter for investigation whether sufficiently strong bearings for slow moving carts cannot be designed to obviate the use of springs. If it is found that this is not possible and that springs are necessary, it may be possible to produce a cheap design using a couple of coil springs in a steel or wooden bearing but its cost is

not likely to be less than about Rs. 15 per wheel. The cost of this construction would thus be as follows:—

Cost of wheel	Rs. 26
„ „ bearings and fixtures..	„ 20
„ „ spring	„ 15
	Rs. 61 for one wheel or
	Rs. 122 per cart.

49. It is possible that bearings may not be used without springs, but that springs may be used without bearings. Wheels of Tongas and Hack-Victorias have springs but no bearings. It is, however, doubtful whether mere springing would help tractive effort to the same extent as improved bearings. If this is possible, and the diameter of a cart wheel can be reduced to about 3 feet without requiring more tractive effort than at present, then a case may be made for their use without bearings. The cost of this equipment would be Rs. 82 per cart. Similarly if bearings could be used without springs, the cost of the equipment would be Rs. 92 per cart.

(d) Alternative Proposals.

50. Thus the following proposals would seem to emerge from this discussion :—

PRICES PRE-WAR.

Method	Cost per cart. Rs.	Present cost. Rs.	Difference per cart. Rs.
(i) A 5 in. composite tyre *without improved* bearings or springs.	59/-	52/-	7/-
(ii) A $6\frac{1}{4}$ in. composite tyre *with* improved bearings *and* springs.	122/-	52/-	70/-
(iii) A $6\frac{1}{4}$ in. composite tyre *with* improved bearings but without springs.	92/-	52/-	40/-
(iv) A $6\frac{1}{4}$ in. composite tyre *with* springs but without improved bearings.	82/-	52/-	30/-

Maintenance on the $6\frac{1}{4}$ in. tyre proposed in Nos. 2, 3 and 4 should be about the same as on the 5 in. tyre proposed in No. 1 as it has a smaller diameter, i.e. Rs. 2/13/- per wheel or Rs. 5/10/- per cart per annum (against Rs. 3/- of the present construction vide para 33) plus a figure for repairing, renewing etc. roller bearings and/or springs. Cost on this item is at present unknown.

51. The pre-war cost of a pneumatic tyre equipment for a bullock cart was about Rs. 140/- i.e. Rs. 90/- over present construction. The cost of a pair of tyres and tubes was about Rs 65/- and their estimated life about 5 years. Hence their maintenance is about Rs. 13/- per annum at pre-war price plus a figure for repairs etc. to roller-bearings. Proposal No. (ii) in para 50 is cheaper than pneumatic tyres both in initial cost and maintenance and it provides work for the wheel-wright industry. But it can never equal or even approximate the efficiency of a pneumatic tyre, which transmits load uniformly over a large area and is much kinder to road surface. Therefore, it would be reasonable to consider this equipment against No. (ii). Further, if it be possible to use parts of war-damaged vehicles the cost of conversion to pneumatic tyres should be less.

52. The above discussion relates to the feasibility of

(a) providing roller-bearings inside the present hub of a cart, and

(b) evolving a cheap design of springs if they are found necessary for the proper functioning of roller-bearings.

The author is doubtful as to whether either of these devices is likely to prove particularly useful in saving roads. Roller bearings will reduce the tractive effort but they will fix the wheels rigidly preventing any play on the axle. This fact will increase impact at every obstacle on a road surface like a depression, pot hole or a high spot. This is not harmful in a pneumatic tyre which is capable of adjusting itself to irregularities in road surface, but with a wooden felloe having a steel tyre the position will be different and very likely the roller-bearings may actually accentuate the harmful effects of impact in a rigid tyre of the type under discussion. On the other hand, the play on the axle in present construction is unregulated which means a sudden side-ways motion of the wheel on the axle as soon as it meets an obstacle. As a result of discussion which he had at Lucknow during September with Rao Bahadur Nageswara Iyer of Madras, it occurs to the author that parhaps this might be controlled by providing a coil spring on the axle between the axle-box and the wheel. If found possible, this would mean that the present wobbling of a cart-wheel, which it is hoped would be checked to a certain extent by the proposed width of the tyre, may be gentler in its damaging effect on road surfaces. It would, however, have no effect on tractive effort like roller-bearings and, therefore, on pay loads. If we decide to cut out pay-loads and concentrate on saving roads, the suggestion may prove useful. Rao Bahadur Nageswara Iyer has certain ideas on this point which will be considered by the Bullock-Cart Sub-Committee.

V. FINANCIAL ASPECTS.

(a) Urban carts.

53. In practice it may be found that improved bearings with or without springs, or springs with or without improved bearings are likely to be useful in the case of a few carts only, *viz.* those which ply all the year round. They will be mostly in and around Presidency towns and in some cases at major district towns. Roads at these places are more expensive than those elsewhere and it would be economical to the community to save them. Better facilities for periodic attention to the carts and their equipment are likely to be available at these places which may also be able to provide garages for carts to protect them from weather so that their equipment may not deteriorate from exposure. Lastly, there would be better facilities for training drivers at such places than at others. Hence there may appear to be a case for the conversion of such carts to a design *using bearings and/or springs.*

54. According to notes (e) and (f) in the Table of Statistical information attached to Mr. Vesugar's paper* on "Proposals for an All-India Survey of bullock-carts etc.", the percentage of urban and rural bullock-carts in the Provinces where separate enumeration was carried out in 1940 was 5.65 per cent. and 94·35 per cent. respectively. Probably these figures may apply to the whole of British India also, but for the sake of argument let us raise the urban figure to 10 per cent. which may be a safe maximum. It is this number which is likely to require bearings and/or springs.

55. It is not easy to decide who should pay for their conversion. There are three parties, *viz.*

(i) the cart-owners who would benefit from better pay-loads,

(ii) the administrations at these places who would save a portion of their road-maintenance bills, and

(iii) the State, who have a general interest in efficient methods of transport and economical road surfaces.

56. At persent the cart transport industry in India is mostly in the hands of individual owners, who are unable to adopt business methods of incurring a capital outlay to earn better dividends. Hence the remaining two parties may have to figure largely in handling this issue. Probably the main point for them to consider may be whether in the event of their agreeing to a subvention for conversion, the cart-owners would bear the cost of all subsequent renewals and replacements. The most costly equipment which can

*Paper J—VIII Proceedings of the I.R.C.

be considered for urban carts is the pneumatic tyre. Particulars of its cost at pre-war prices are as follows :—

Roller bearings	....	Rs 30/-
Tyres and tubes	....	Rs 65/-
Wheels and axle	....	Rs 45/-
		Rs 140/-

Repairs to and replacements of bearings, tyres and tubes should form part of maintenance. The main items for renewal are thus wheels and axle. Their cost is less than the cost of a pair of wheels in present construction which is Rs 52/-. Hence *there should be no difficulty in cart owners paying for the renewal of wheels whenever they are due for renewal.*

(b) Rural carts.

57. The question of the remaining 90 per cent. of the carts is comparatively simple. All they need is a wide felloe without any major changes either in the cart or the wheel. The cart-owner derives no benefit from this improvement which is solely in the interests of roads, there being no question here of better pay-loads. Therefore, the responsibility for their conversion should be taken up solely by the State. If the cost of the improvement is fairly cheap and within the means of the owners, as seems to be the case with the design discussed in this paper, it should not be difficult for them to bear the cost of renewals. It may also happen that once a design is standardised the cost of producing it after a period of years may not be more than that of the present construction. Therefore, here also there should be no difficulty in owners paying for renewals. As regards maintenance the State should fix by law a suitable minimum hire which should be so much above the present minimum hire, as to compensate the owners for the extra cost of maintenance which should cover repairs to and replacements of bearings where they are provided Thus *by separating maintenance from renewals, a case can be made for meeting the cost of the former from increased hire charges and of the latter from the normal expenditure which cart owners would have incurred on renewals in the present construction.* The only issue to be tackled would be to finance the initial conversion, which, the author suggests the State should bear.

(c) Time and cost of conversion.

58. Probably the best time for bringing about conversion may be when a wheel is due for renewal. In that case the amount spent on present construction is fully utilised and the amount of subvention is reduced by the amount of present construction which the owner

would normally incur on renewal. Further, the procedure would likely be more popular than a whole-sale conversion in one bound. Since the average life of the present wheel is about 15 years, the entire cart-population in British India may reasonably be expected to be converted in this manner in a period of 15 to 20 years.

59. Deducting the cost of present construction the amount of subvention payable per cart for the various proposals discussed above would be as mentioned in para 50.

60. The amounts of subventions required in several proposals indicated in para 50 are detailed below :—

	Cost (pre-war) in Crores of Rs.
(a) Conversion of all $6\frac{1}{4}$ million carts to broad wooden felloe as in Plate II *without* springs or bearings.	4·37
(b) Conversion of rural carts (90 per cent.) to (a) above and urban carts (10 per cent.) to (a) with *springs* and *rollers*.	8.31
(c) as in (b) with *pneumatic tyres* extra for urban carts.	9·44
(d) Conversion as in (a) above, with *bearings* extra for urban carts.	6.44
(e) Conversion as in (a) above with *springs* extra for urban carts.	5.81

The post-war cost of (c) above will be Rs. 11.25 crores on the assumption that there will be no increase in the cost of pneumatic equipment on account of the large-scale production.

(d) Hasten slowly.

61. Though the ultimate solution of the bullock-cart problem lies in the use of pneumatic tyres, experience of the past 12 years or so since these tyres were introduced indicates that the country is not yet ready for the change. This seems to be due mainly to the extra cost involved in initial conversion, annual maintenance and care of pneumatic tyre equipment in the off agricultural season, and the difficulty of attending regularly to proper repairs and maintenance of this important equipment. Also a wholesale conversion of pnuematic carts will throw out of employment about 2 lakhs of people now employed in the cart industry and in the present economic state of this country, it is doubtful whether this wholesale conversion will be welcomed.

62. In the opinion of the author, the immediate economic possibility is to provide in the next 20 years all the rural carts with broad rimmed tyres and the urban carts with pneumatic tyres with springs and roller bearings, at a cost of Rs. 11.25 crores. The existing carts will also become due for renewal in this period. The extra post-war annual maintenance in the case of pneumatic tyres is Rs. 18/. (para 50) and Rs. 4/- in the case of carts with broad felloes. (Table II). With an average possible annual earning of Rs. 1,000/- and Rs. 400/- by the two types, the extra maintenance works to $1\frac{3}{4}$ per cent. The author suggests that the Government should grant a subsidy of Rs. 11.25 crores, and permit by legislation the necessary increase in hire-charges to meet the extra maintenance.

63. This suggestion however is likely to be open to two objections, (i) certain elements of the community may object to the principle of the State fixing statutory minimum hire-charges as an encroachment on their rights and, (ii) the law of demand and supply may make the statutory provision inoperative in practice.

It must be remembered that a rural cart-owner has to ply his cart to keep his bullocks employed and may find it difficult not to do so till he obtains particular hire. *To the author's mind perhaps a better proposal may be for the Government to supply, free of cost, tyres as and when required, both for new construction and maintenance, in exchange for old tyres in every case.* In the case of steel tyres this proposal may seem to have the following advantages:—

(i) Reduction in the cost of construction and maintenance to practically the same level as at present. Cart-owners can have no objection to the State legislation for a particular type of wheel.

(ii) The wheel-wrights will not be affected in any way.

(iii) No need to fix minimum hire-charges.

(iv) Proper utilization by the State of all scrap iron from old steel tyres, not possible at present by individual cart-owners.

(v) Possible less cost due to mass production to standard sizes.

(iv) Standard dimensions of tyres in machine production with the elimination of variations in the diameters of the 3 bands of steel tyre in hand made types.

64. In a three-tyre design of wheel, with 70 lbs. of steel, costing Rs. 5/- the salvage at the time of replacement will be 30 lbs. of steel at an estimated cost of Rs. 1/-. Thus the nett cost of steel tyres for the two wheels will be Rs. $2\times(5-1)$ or Rs 8/- in 7 years.

This works to an annual charge (pre-war) of Rs. 1/2 per cart or about Rs. 71 lakhs for the entire cart-population. At post-war rates, this figure may be taken as Rs. one crore or about 8 per cent. of the estimated maintenance bill of Rs. 12 crores in British India according to the Nagpur Report. The author considers that the resulting savings in road maintenance bill by the use of the new type of wheel, will more than offset this extra expenditure of Rs. one crore. Similar information about pneumatic tyres should be obtained from suppliers for this equipment.

65. There is no point in justifying, at the present stage, this conversion on figures of savings in road maintenance as no reliable data are available. In the first place our roads carry mixed traffic and it is not known how much of their maintenance is due to motor traffic and how much to cart traffic. Secondly maintenance of a road surface is generally based more on what amount is available than on what is required and, thirdly traffic keeps changing. Lastly, till broad-rimmed tyres are actually employed, we shall have no means of ascertaining their effect on road maintenance.

(e) Author's approach.

66. The author's approach to the problem is that it is a fair assumption that broad-rimmed tyres would reduce damage to road surfaces by reducing the load transmitted to them. Further, they may not require the heavy specifications for road construction, which the present narrow tyres render necessary in certain cases. Therefore, their adoption should form part of a Road Development Scheme. On this reasoning the author would suggest that even if a subvention be not forthcoming from the Government of India, the scheme of Rs. 11.25 crores envisaged in this paper should form part of the Chief Engineer's Road Plan of Rs. 450 crores to be executed simultaneously with it.

67. It may be mentioned here that all the figures discussed in this paper are based on methods of construction employed in the City of Bombay where the cost of materials, standard of workmanship, design and labour are fairly high. An average figure for the whole of British India is not unlikely to be materially below these figures. Therefore, the amount of subvention is likely to be below the figures indicated in the above para.

VI. Summary of Conclusions.

68. The main proposals in this paper may be summarised as follows :—

(1) To reduce the damage caused by the existing narrow steel tyres of bullock-cart wheels, and to improve the efficiency of the carts, two designs are discussed:—

(a) Increasing the width of the steel tyre only.

(b) Increasing the width of the steel tyre and providing roller or ball bearings and/or springs.

The designs proposed will make use of the same materials and methods of construction as followed by the village wheel-wrights and hence their industry will not be affected.

(2) The designs are primarily meant for the *S*-type wheel but are suitable for the heavier *A*-type wheels also.

(3) Particulars of the two types are described (Table I) and paras 50 and 56.

(4) The evolution of the designs and the reasons for the dimensions proposed are discussed. The main considerations are :—

(a) need for retaining steel tyre,

(b) the limitation of width of steel tyre, without affecting the tractive effort, to 5 in. and to 6¼ in. with improved bearings,

(c) limitation in the thickness of the steel tyre and the diameter of the wheel, to keep the weight of steel as at present and to keep it below the weight of the wooden felloe for stuctural stability; and the evolution of the three-band tyre with 2 end tyres 1¾ in. × ½ in. and a central band 2½ in. × 3/16 in.

(d) The adaptability of the design to the heavier *A*-type thus reducing its weight.

(5) Standard roller bearings inside the hub can be provided without changing the construction of an *S*-type wheel. A cheap design for springs is indicated. The need for either or both is discussed.

(6) Design with improved bearings with or without springs, or springs without bearings is likely to be useful for carts in urban areas only. The same is true of pneumatic tyres; rural carts do not need them; their requirement is a broad felloe to save roads.

(7) There is no point in making out a case for better pay-loads as a result of the adoption of proposal No. 6 as the cart industry is in the hands of individual owners who cannot afford capital outlay even when it is remunerative. They can afford renewals of wheels so long as they can meet their maintenance out of hire-charges.

(8) The maximum number of urban carts is not likely to be more than 10 per cent. of the present cart-population of $6\frac{1}{4}$ million in British India. The remaining 90 per cent. are rural carts.

(9) The best time for conversion is when a wheel is due for renewal as in that case the amount of subvention on conversion is reduced by the cost of present construction which the owner would bear normally on a renewal.

(10) The amount of State subvention necessary for different alternatives is discussed, in para (60).

The conversion of rural carts to broad felloes, and steel tyres and the provision of pneumatic tyre equipment with improved bearings, and springs, to urban carts at a cost of Rs. 11.25 crores (post-war) are recommended. The extra maintenance of wheels is estimated to be from 1 per cent to $1\frac{3}{4}$ per cent. which can be covered by State Legislation of minimum hire charges.

(11) The State should give a subvention of Rs. 11.25 crores for the conversion; the conversion should form part of the Road Plan of Rs. 450 crores to be executed simultaneously with it. Alternatively, the State should supply, free of cost, tyres to all carts both for new construction and maintenance, at an estimated cost of Rs. one crore, representing only 8 per cent. of the anticipated road maintenance bill. The savings in the road maintenance bill by the lesser damage caused by the new types of wheels will more than pay for this free supply of tyres. Construction of tyres will also be standardized.

TABLE I

Details of wheels *S* and *A* Types

Part or items.	*S*-Type.			*A*-Type.		
	Existing Plate I.	Proposed design a. Plate II.	Proposed design b. Plate VII	Existing Plate III	Proposed. Interim design Plate IV	Proposed. Final design Plate IV
1	2	3	4	5	6	7
(a) Details.						
Felloe— width— in.	2.25	5·00	6·25	5·00	5·00	5·00
depth— in.	6·25	4·125	4·13	11 00	4·75	6·63
section— sq. in.	16·25	21·00	23·75	55·00	23·75	33·13
Spokes or arms.						
No. in section 2″×4″	—	—	—	4	8	12
No. in section 2½″×2½″	—	—	—	4	4	—
No. in section 3⅜″×2″	12	12	12	—	—	—
Hub—width— in.	14	10·5	14	14	14	14
depth— in.	10.5(dr)	—	10·5 dr.	14	18	13
Steel Types						
No. × width in. × thickness in.	1×2¼×⅝	2×1¼×½	2×1¼×½	No steel tyre	2×1¼×½	2×1¼×½
area—sq in.	1·40	1·25	1·25	—	1·25	1·25
Weight. lbs.	65	50				
Wheel						
Diameter ft -in.	4′—3¾″	3′—9¾″	3′-0′	3′-10′	3′-10″	3′-10″
Weight lbs.	209	201	179	275	256	256
Body—weight in lbs.	532	—	—	820	—	—
Load—carrying capacity cwts.	16·00	16·00		*		
Total laden wt. cwts.	26·80	26·80				
Per in. width of Tyre lbs.	667	300	240			
(b) Cost of Construction in Rupees (All pre-war)						
1. Body	73	—	—	75		
2. 2 wheels	52	59	52	50		
3. Cart	125	—	—	125		
4. Springs	—	—	30			
5. Roller bearings	—	—	40			
6. Springs and roller bearings.	—	—	70			
7. 2 wheels plus springs and roller bearings	—	—	122			
(c) Annual maintenance (Rupees) (pre-war)						
1. Steel tyre or tyres	2-14-0	3-14-0	3-14-0	4-10-0		
2. Steel tyres and central band	—	5- 8-0	5- 8-0	—		
3. Wooden felloe in *A*-Type		—	—	4- 0-0 for earth roads.		

*14 cwts. on sandy roads and 36 cwts. on hard types.

Table II

Cost of construction and maintenance of bullock-cart wheels (2 types)

Details	Existing wheel (Plate I) Qty.	Rate	Per	Amount	Proposed wheel (Plate II) Qty.	Rate	Per	Amount
(a) Construction Materials								
(i) Wood								
Felloe (Cu. ft.)	2.67	[illegible]	Cu.ft	[illegible]	1.75	[illegible]	Cu ft	[illegible]
Spokes (,,)	1.00	2-0-0	,,	2-0-0	1.00	2-0-0	,,	2-0-0
Hub (,,)	1.25	2-8-0	,,	3-2-0	1.25	2-8-0	,,	3-2-0
(ii) Steel								
Tyre (lbs.)	6? 28	[illegible]	Cwt.	[illegible]	[illegible] 28	[illegible]	Cwt.	[illegible]
				17-2-0				[illegible]
Labour								
For felloe ...				[illegible]				[illegible]
For fixing steel tyre				[illegible]				[illegible]
For fixing hub				[illegible]				[illegible]
		Total labour		[illegible]				[illegible]
		Total cost		[illegible]				[illegible]
Add [illegible] for [illegible]				[illegible]				[illegible]
				[illegible]				[illegible]
Extra cost of proposed wheel								[illegible]
,, ,, a cart								[illegible]
								[illegible]
(b) Maintenance (annual) (i) For maintaining steel tyres								
Removing and refixing steel tyre	1	[illegible]	each	[illegible]	[illegible]	[illegible]	each	[illegible]
Renewal of steel tyre [illegible]		[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]
Total [illegible]				[illegible]				[illegible]
[illegible] in the [illegible]				[illegible]				[illegible]

Difference in cost of maintenance, [illegible]

(ii) For maintaining steel tyres and [illegible] proposed wheel.

As in (b) (i)		[illegible]
Providing [illegible] steel band in the centre, including cost and labour	[illegible]	[illegible]
	[illegible]	[illegible]
Refixing annually		Rs. [illegible]
[illegible] the present [illegible]	Rs.	[illegible]
Difference in cost of maintenance [illegible]	Rs.	[illegible]

Appendix A.

PARTICULARS OF 13 ALTERNATIVE DESIGNS REFERRED TO IN PARA 42 OF THE PAPER.

(See Plate V)

1. A wooden tyre for an S-wheel. The idea in this design is to have a 3 in. deep wooden felloe superimposed with a 5/16 in. steel tyre in the usual way and then to fix to it with bolts and nuts a wooden T-Section 5 in. wide, 2 in. deep with a 2 in. leg as shown in the sketch.

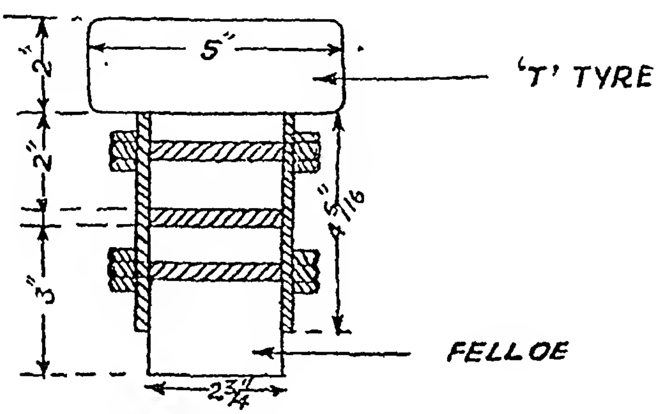


FIG. 5

2. It will be seen that this design meets the two main requirements of a felloe *viz.* a depth of 2 in. for wear and tear and 3 in. for stability for a width of 2½ in. The 5/16 in. steel tyre should be sufficient for the stability of this assembly. But the section would be heavy both on account of extra wood for the leg of the T and steel for flanges and bolts. Therefore, the diameter of the wheel would have to be reduced to keep down weight. Above all, it involves the use of bolts and nuts in an unseasoned wood which is continually subject to wet and dry weather. This fact coupled with the jerks which a felloe is bound to receive in its travel over a road surface would widen the bolt holes, the nuts would get loose from time to time and the combination would, on the whole, be unsatisfactory. *The author is of the definite opinion that any construction involving the use of bolts and nuts in the felloe of a cart wheel is open to grave objections and is not likely to prove either satisfactory or popular in the long run.*

3. **Steel tyre**: See (1) in Plate V. The idea underlying this design is the same as in the proposed design but the width of the felloe has been reduced by 3/4 in. to lighten it. Inspite of it the section is heavy and for the same weight the wheel diameter has to be reduced to 3 ft. Its cost would be the same as in present construction but the diameter would affect appreciably tractive effort.

With an ½ in. thick steel tyre instead of 5/8 in. the diameter of the wheel in this design would be 3 ft. 3 in. for the same weight as in present construction. This also would not be satisfactory for tractive effort. If the diameter is increased to 3 ft. 10 in. as in the proposed design, then, for the same weight of wheel the width of the felloe in this design using ½ in. thick steel tyre would be a little less than 3¾ in. which also is not satisfactory.

4. **Stuffed rubber-tyre**: See (2) in Plate V. The idea in this design is to superimpose on the normal felloe a rubber tyre stuffed with chopped hay. This procedure will obviate the need to maintain air pressure, and to repair punctures in a pneumatic tyre. The design, however, is not feasible, because, (a) it entails the use of bolts and nuts, (b) for the same weight the diameter of the wheel would be 40 in. against 46 in. in the proposed design, and (c) lastly its cost would be more than double that of present construction i.e. Rs. 55/- against Rs. 26/- per wheel at pre-war prices.

5. *Burgess Wheel*: See (3) Plate V. This design was placed before the Bullock-Cart Sub-Committee of the Council of the Indian Roads Congress in March last in Bombay. The design is unstable as the two ½ in. × 1/4 in. Wrought Iron tyres proposed are too weak to hold the assembly tightly. If it is intended that the load should be taken up by the rope tyre only, the effective width will be only 3 in. against 2½ in. in the present construction and 5 in. in the proposed design. Maintenance on the rope tyre is an unknown factor and it may not be easy to keep the rope in place without difficulty. The good point of this construction is that it avoids bolts and nuts.

6. *Nos. 4 to 9 in Plate* V. are all Mr. Murrell's designs. They have been very carefully thought out but particulars of weight, diameter of wheel and costs of construction and maintenance have not been given. To the author's mind all except No. 9 appear to be meant for an *A*-type wheel. If adopted for the *S*-wheel they would require the same constructions as in Nos. 1 and 3 discussed above. In both cases the author feels that they are open to two objections, (1) the use of bolts and nuts and, (2) extra weight. The cost also is not likely to be low.

7. *No. 9 Plate V.* This is also Mr. Murrell's design but for

an *S*-type wheel. This is open to the same objections as No. 1 and, further that it would require more steel in its construction than that design, thus making the wheel heavy and costly. Mr. Murrell's design No. 8 for an *A*-wheel is sound but the author would suggest that the two proposed steel plates and bolts and nuts be dropped and the spokes be driven through the felloe using wedges and dowels for fixing it. This would cheapen the construction. The *A*-type wheel seems to be meant for such construction and a rectangular felloe would suit it better than a T-section which is not cheaper. Maintenance on a wooden tyre would be heavy according to experience in Ahmedabad and a wooden tyre has to be renewed often. *In the author's opinion the replacement of one type of wooden tyre by another is no proper solution of this problem. To save maintenance steel has to be employed and the aim should be to widen the felloe as much as possible with the use of minimum steel.*

8. *No.* 10 *Plate* V. This design was submitted by Mr. M. Gnana-Mani of Tellicherry with his comments on Mr. Murrell's paper. "The steel tyre problem unfolds" and has been given in Page. 77 (g) of the 1941 Proceedings of the Indian Roads Congress. To the author's mind the constructional defects of the design are the use of, (1) screws to hold the steel tyre, and, (2) a 1/4 in. thick steel tyre for the assembly which is too thin to hold it tightly. In unseasoned wood screws should fare worse than bolts and in the construction proposed they cannot be got at without removing the rope tyre. When the rope tyre flattens out the entire load will be thrown on the two curved ends of the steel tyre, which can hardly bear it. If the rope tyre is thickened and made to project about 5/8 in. like a tonga tyre, its effective width would be only 2¾ in. against 2¼ in. in present construction. In an *A*-wheel this construction would provide too thin a cushion to protect the spokes from damage due to impact.

9. Cumming wheel: This is an all-steel wheel of a diameter of 3ft.6 in. It consists of a 4in. tyre made up of two angles 2 in. × 2 in. × ¼ in. with eight ½ in. rivets in between adjacent spokes. It has 8 spokes consisting of 1¼ in. × 3/8 in. flats welded to the hub and rim. The flats form a cone which is supported in the centre with a 5/8 in. round bar also welded. The hub consists of an 8 in. × 5 in. wrought-iron pipe with a self-lubricating arrangement. *This construction is beyond the capacity of village wheelwrights.* In the author's opinion its other defects are (1) heaviness, (2) a small wheel-diameter, and (3) the use of a ¼ in. thick rim to take up wear and tear. The width of rim is 4 in. against 5 in. in the proposed design. The author has not seen this wheel but he has received a report that the design is very heavy and, therefore, not popular.

Appendix B.

NOTE ON THE STRUCTURAL STABILITY OF PRESENT AND PROPOSED DESIGNS FOR THE WHEEL OF A BULLOCK CART

By Professor Taraporewala of the College of Engineering, Poona.

1. The following pages contain an analysis of the stresses in the present and proposed designs for the bullock cart wheels, both when new and when the felloe wears out by 2 in. during the life-time of the wheel. The stresses considered are those due to :—

i) Shrinkage,

ii) Bending moment, and

iii) Torsion.

2, It will be seen that all the stresses are within permissible limits for both designs. The bending and torsional stresses due to live loads seem to be negligible in comparison with shrinkage stresses. The torsional stresses in the new design are practically the same as in the present one.

3. The spokes in the new wheel are stronger, as with the increased width of the felloe, and the consequent reduction in these lengths, these become broad-based columns. On the other hand, there is a greater tendency in this design towards twisting of the felloe due to its greater width especially when the wheel mounts a stone away from the centre line. This effect may also be produced if there is uneven shrinkage in the two steel tyres. This tendency is likely to be counteracted by the provision of a third central steel band 3/16 in. thick which it is understood is proposed to be provided in the centre of this felloe. If the Central tyre is shrunk on first, it will make the rim sufficiently rigid to resist the twisting action of uneven shrinkage due to the outside tyres. However, the central tyre will bring in its own problems. If it gets loose one of the outside tyres will have to be removed before it can be shrunk on. Besides with three independent tyres, one or the other may tend to get loose oftener. A better solution would be to use a single tyre 5 in. by 3/8 in. but it is understood, it would be costlier.

4. The effect of reduced diameter on tractive resistance will be only about 5 per cent. (See statement I) and may, therefore, be neglected.

5. The broad rim of this design will have no effect on tractive resistance. On the other hand, it may reduce friction on bad roads due to less penetration of the wheel in the road surfaces (See statement II which represents the findings of Missouri Agricultural Experiments Station). After a series of experiments, Morin, a French engineer, concluded that the harder the surface of a road the less the effect of the width of tyre on rolling resistance.

6. With regard to roller-bearings, there are two viewpoints to consider. If the cart can carry say 10 per cent. more load with the same bullocks it may perhaps pay for the extra cost and unkeep. But from the point of view of the road, it will bring about a big saving. It will be observed that the pressure on the road is (for the existing wheel) round about 700 lbs. per sq. in. which is within the capacity of the materials used in road construction. What wears out a road surface is not so much this pressure as the abrasion caused by the sliding movement of the cart wheel transversely to the road, due to the wheel being improperly positioned on the axle. (The greater wear of the road on curves is due to the same cause, the sliding of the vehicle), The moment this transverse wobble, which consists of both the slide and the change in the plane of the wheel, is prevented by any arrangement (and it would be if roller bearings are used) the wear of the road will be materially reduced. The proof of the above cause of road-wear is to be found in the case of motor cars with independent springing. In the case of one commonly-adopted type, the front wheels, under road obstacles, behave exactly like cart wheels, slide transversely as well as change their plane. This scrubbing action is responsible for the quicker wear of the tyres of the independently sprung cars as compared with those not so equipped. In the case of a soft material like rubber it is the rubber that wears out and not so much the road surface as it is harder, whereas it is the reverse in the case of bullock carts, the steel tyre being harder than the road surface.

7. In considering the economics of roller-bearings, their increasing use on railways may be noted. It has been suggested that fixing the wheel position, as with a roller-bearing, will wear out the road quicker. A simple calculation (given in the appendix) shows that the effect of fixity is to prevent the sliding of the cart transversely even though one of the wheels is standing on an obstacle inclined 45° to the horizontal. The nett result is that the reaction or the force or the push on the obstacle, a stone for instance, is inclined at an angle of 15° or more. This inclined force tends to uproot the stones from surface of the road and so wear out the road. But this can happen only when the surface of the road has already worn out, presenting such obstacles.

8. When the surface of the road is good, and the wheels are not fixed in position, there will not be a smooth rolling action on

the road. The sliding of the wheel engenders slackness in the axle leading to wheel wobble.

9. Wobble, in the main, is nothing but the oscillation of the wheel about two perpendicular axles, both passing through the centre of the boss, one horizontal and parallel to the length of the road and the other vertical. One has only to watch the harness in the necks of the bullocks to notice the constant change in the pull required to haul the cart, entirely due to wheel wobble when the cart is moving on a smooth concrete road.

10. We may, therefore, conclude that fixity of wheel position will spare the road, if its surface is fairly good, but will wear out the road faster if the surface is already torn and rough.

11. With regard to using a spring on the axle it will add to the cost of a cart without any material compensating advantage. It may reduce the wobble slightly Besides, the length of the axle would have to be increased to accommodate the spring. One balance it is not worth while.

12. With regard to springs, again there are two opposite view-points to consider. From the viewpoint of the cart-owner, it is an accretion being wholly unnecessary, and an economic drag, the extra cost and upkeep not being counterbalanced by any extra earning power as in the case of roller bearings. From the point of view of the road, if it has an uneven surface, springs would materially reduce the impact and so the wear and tear on it. If the surface is prefectly smooth, we may take it that the springs would help to reduce the wear on the road. As a simple illustration we may imagine the cart wheel lifted 1 in. by a road obstacle and then falling 1 inch. The work done will be equal to the wheel reaction multiplied by the fall of 1 inch. This work will have to be absorbed, in the main by the crushing of the road material, if no springs are used. But if the springs are provided, the work will be absorbed, in the main, by the deflection of the spring and the road will be materially relieved of the wear and tear.

13. As the road keeps on improving, the importance of springing will be less. For a people's cart, to bring down its price to within the range of the average pocket, it has been seriously proposed that springs be omitted, what little springing is necessary for billiard-table roads of Great Britain, being provided by the tyres themselves.

14. While it is posible to persuade the cart-owner to go in for the second type of wheel with the wider tread and ball bearings, perhaps, from his own economic point of view, it would be impossible to do so in the case of springs. Besides, in the absence of precise data showing the saving of the road by the introduction of springs, it would not be right to spend public funds on the supply of springs to the cart-owners.

STATEMENT I.

EFFECT OF SIZE OF WHEELS ON TRACTIVE RESISTANCE.

Serial No.	Description of Road Surface.	Tractive resistance in lbs. per ton on wheels, with mean diameters in inches of front and rear wheels of		
		50	38	26
1	Macadam, slightly worn, fair condition	57	61	70
2	Gravel Road, sand 1 in. deep, loose stones	84	90	110
3	″ ″ upgrade 2.2 per cent one-half inch wet sand, frozen below.	123	132	173
4	Earth road. Dry and hard	69	75	79
5	″ ″ ½ in. sticky mud, frozen below	101	119	139
6	Timothy & blue grass sod. Dry grass cut	132	145	179
7	″ ″ ″ wet and spongy:	173	203	281
8	Cornfield; flat culture across rows, dry	178	201	265
9	Plowed ground; not harrowed dry and cloddy	252	303	374
	Average value of Tractive Power	130	148	186

The increase in tractive effort for a decrease of 12 in. in wheel diameter works to 6 lbs. per ton in the case of gravel and earth roads (items 2 and 4) and 4 lbs. per ton in the case of Macadam Roads (Item 1). The average increase in tractive effort may be taken as 5 lbs. per ton for these three types. Assuming a proportionate difference in this tractive resistance for other diameters, for a reduction in wheel diameter of 6¾ inches between the existing and the proposed types of wheels, the increased tractive resistance per ton will be $\frac{5 \times 6.75}{12}$ or 2·81 lbs. With a normal resistance of 60 lbs. per ton for the existing larger wheel, the percentage increase in the tractive resistance for the proposed smaller wheel will be $\frac{2.81 \times 100}{60}$ or 4.7.

Statement II.

TRACTIVE RESISTANCE OF BROAD AND NARROW TYRES.

Sr. No.	Description of Road Surface.	In lbs. per ton for tyre width 1½ in.	6 in.	No. of trials
	Macadam Road.			
1.	Hard, smooth, no dust, no loose stones.	121	98	2
	Gravel Roads.			
2.	Hard, smooth; a few loose stones.	182	134	2
3.	Hard no ruts, large quantity of sand.	239	157	1
4.	New gravel, not compact, dry.	330	260	1
5.	Wet, loose sand 1 in. to 2½ in. deep.	246	254	2
	Earth Roads.			
6.	Loam, dry, loose dust 2 in. to 3 in. deep.	90	306	2
7.	Loam dry and hard, no dust, no ruts.	149	109	3
8.	Stiff mud, drying on top, spongy below.	497	307	1
9.	Mud 2½ in. deep, firm below.	251	325	1
10.	Clay, sloppy mud, 3 in. to 4 in. deep, hard below.	286	406	1
11.	Clay dry on top but spongy below.	472	422	2
12.	Clay dry on top but spongy below.	618	464	5
13.	Stiff deep mud.	825	551	1
	Mowing Land.			
14.	Timothy sod, dry firm and smooth.	317	229	1
15.	Sod moist.	421	305	1
16.	Soft and spongy.	569	327	1
	Pasture Land.			
17.	Blue grass sod, dry, firm and smooth.	218	156	2
18.	Sod soft.	420	273	2
19.	Sod soft.	578	436	1
	Stubble Land.			
20.	Corn stubble, no weeds, dry enough to plough.	631	418	2
21.	Stubble, some weeds, dry enough to plough.	423	362	1
22.	Stubble dry and firm.	404	256	2
	Ploughed Land.			
23.	Freshly ploughed, not harrowed, surface rough.	510	283	1
24.	Freshly ploughed, harrowed, smooth, compact.	466	323	1

N. B. Except in mud 2½ in. to 4 in. deep (Nos. 9 and 10) and dry loose dust 2 in. to 3 in. deep (No. 6), tractive resistance of a broad tyre is less that of a narrow one.

Appendix B.—*Contd.*

ANALYSIS OF STRESSES

Notation.

D = Diameter of wheel without tyre.

d = Difference in diameter to affect shrinkage (assumed as $\frac{1}{8}$ in.)

p = Pressure at common surface of contact.

t_A = Radial thickness of felloe.

t_B = Radial thickness of steel tyre.

E_A = Elastic Modulus of wood = $1 \cdot 5 \times 10^6$ lbs. per sq. in.

E_B = Elastic Modulus of Steel = 30×10^6 lbs. per sq. in.

f_A = Stress in wood.

f_B = Stress in steel tyre.

e_A = Strain in wood.

e_B = Strain in steel.

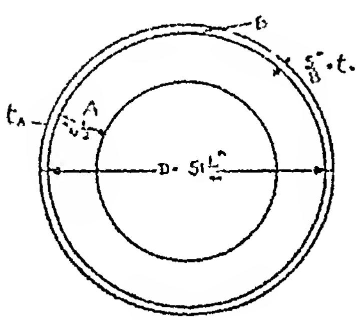


FIG. 7

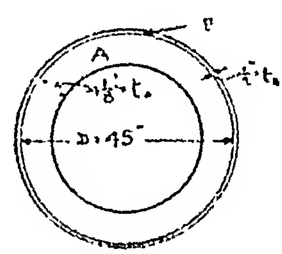


FIG 8

I. Shrinkage Stresses.

$$f_A = \frac{p\,D}{2\,t_A};\quad f_B = \frac{p\,D}{2\,t_B} \ldots\ldots\ldots\ldots\ldots\ldots\text{(i)}$$

$$e_A = \frac{f_A}{E_A} = \frac{p\,D}{2\,t_A\,E_A};\quad e_B = \frac{f_B}{E_B} = \frac{p\,D}{2 t_B\,E_B} \ldots\ldots\text{(ii)}$$

$$d = D\left(e_A + e_B\right) = \frac{p\,D^2}{2}\left\{\frac{1}{t_A\,E_A} + \frac{1}{t_B\,E_B}\right\}\ldots\text{(iii)}$$

The shrinkage stresses in the existing and proposed wheels, when new and after two inches wear in the felloe, by substituting the suitable values in equations (iii) and (i), are given below :—

	in inches				in lbs. per sq. in. [Eqn. (i)]		
. . .	D	t_A	t_B	d	p Eqn. (iii)	Stress in wood e_A	Stress in Steel e
(a) Existing wheel new.	51·5	6·5	0·625	0·125	609	3,500	25,000
(b) Existing wheel after 2 inches wear in the felloe.	47·5	4·5	0·625	0·125	553	2,920	21,000
(c) Proposed wheel when new.	45·0	4·125	0·50	0·125	840	2,290	37,800
(d) Proposed wheel after 2 in. wear in the felloe.	41·0	2·125	0·50	0·125	669	3,220	27,400

II. **Bending Stresses.**

(i) *Stress in wood assuming timber alone takes the stress.*

If S = the span of the felloe $= \frac{\pi}{12}\left(D - t_A\right)$ inches....(iv)

R = wheel reaction including 100 per cent. impact 3000 lbs,

M = bending moment = $\frac{RS}{6}$ in. lbs..................(v)

b = width of felloe

Z = Modulus of section = $\frac{1}{6}bt^2_A$...................(vi)

f_A = Stress in wood = $\frac{M}{Z}$ ....(vii)

the values of f_A in the existing and proposed wheels, when new and after a wear of 2 in. in the felloe, are as under :—

		in inches				Z in.³ Eqn. (vi)	M in lbs. Eqn. (v)	Stress f_A lbs. per sq. in. Eqn. (vii)
		D	t_A	S Eqn. (iv)	b			
(a)	Existing wheel when new.	51·5	6·5	11·8	2·5	17·6	5,900	335
(b)	Existing wheel after 2 in. wear in felloe.	47·5	4·5	12·3	2·5	8·45	5,650	699
(c)	New wheel when new.	45·0	4·375	10·64	5	16·0	5,320	333
(d)	New wheel after 2 in. wear in felloe.	41·0	2·375	10·32	5	4·7	5,160	1,098

(ii) Stress in Steel

Due to Shrinkage Stresses, the felloe becomes actually a pre-stressed beam, in which the tyre and the rim act in unison exactly like a pre-stressed *Reinforced Concrete beam.* This action is possible so long as p the Shrinkage pressure produces a frictional component mp, (where m is the co-efficient of friction taken as 0·3), equal to or greater than the shear stress p^1 at the common surface of contact, when considered as a compound beam.

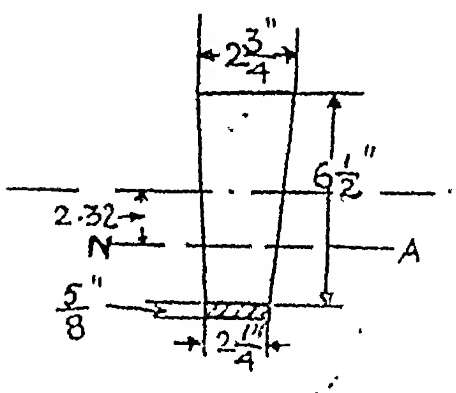


FIG. 9

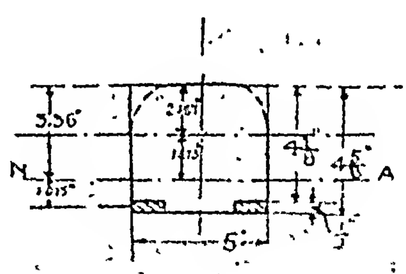


FIG 10

Felloe as a Compound beam.

$$\text{Modulur Ratio } M = \frac{E_A}{B} = 20$$

If y is the distance of the neutral axis from the top, taking moments about the top.

$$y\,(2{\cdot}25 \times 0{\cdot}625 \times 20 + 6{\cdot}5 \times 2{\cdot}5) = 2{\cdot}25 \times 0{\cdot}625 \times 20 \times 6{\cdot}81 + \frac{2{\cdot}25 + 6{\cdot}5^2}{2} + \frac{0{\cdot}5 \times 6{\cdot}5^2}{2 \times 3}$$

or $y = 5{\cdot}46$ inches.

$$I_{N.A.} = \frac{2{\cdot}5 \times 6{\cdot}5^3}{12} + 16{\cdot}25 \times 2{\cdot}21^2 + 28{\cdot}13 \times 1{\cdot}35^2$$

$= 187{\cdot}60$ in.^{4}

$$\text{Compression Section modulus } Z_C = \frac{187{\cdot}60}{1{\cdot}35} = 139 \text{ in}^3.$$

$$\text{Tension section modulus } Z_T = \frac{187{\cdot}60}{5{\cdot}46} = 34{\cdot}4 \text{ in}^3.$$

Shear Stress at the common surface of contact p^1 is given by

$$p^1 = \frac{PAy'}{b\,I}$$

where p = 1500 lbs. with impact
A = 28·12 sq. in.
Y_1 = 1·35 in.
b = 2.5 in.
I = 187·60 in^4.

= 121·4 lbs. per sq. in.

The minimum amount of compression required at the common surface of contact must be greater than $\frac{121{\cdot}4}{0{\cdot}3}$ or 405 lbs. per sq. in.

Since the compression developed at the common surface is 509 lbs. per sq. in. (page 92), the felloe will behave as a compound beam.

Stress in wood $= \frac{\text{B.M.}}{Z_c}$; stress in steel = 20 × stress in wood . . (ix)

The values for these stresses in the existing and proposed designs in the two conditions when the wheel is new, and when the felloe is worn out by 2 inches, are tabulated below.

	Distance of C. of G from top. in.	Equivalent I in^4.	Section modulus compression Z_c—in^3.	Bending moment in. lbs.	Compressive stress lbs. per Sq. in.	
					in wood.	in steel.
1	2	3	4	5	6	7
(a) Existing wheel-new	5·46	187·6	139	5900	42·4	848
(b) Existing wheel after 2 in. wear in the felloe.	4·08	70·1	96·0	5650	58·6	1172
(c) Proposed wheel-new	3·36	90·75	88·5	5320	60·10	1202
(d) Proposed wheel after 2 in. wear in the felloe.	2·12	17·55	69·6	5160	75·5	1510

III. TORSIONAL STRESSES.

If R = wheel reaction including 100 per cent. impact = 3000 lbs.

T = torque in in. lbs.,

S = maximum shear stress due to torque,

hen $S = T\dfrac{15d+9b}{5d^2b^2}$ .... (x)

Existing wheel.

Torque $T = R \times 1 = 3000$ in lbs.

$$\therefore S=\frac{15\times6.5+9\times2.5}{5\times6.5^2\times2.5^2}T \text{ from eqn. (x)}$$

$=270$ lbs. per sq. in.

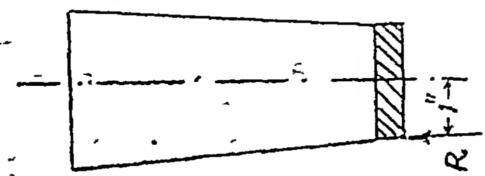


FIG. 11

Actually, as for bending, the tyre will help the felloe materially in resisting torsion, and therefore the stress will be much less than the above value. As an approximation, we may take the reduction ratio as for bending, *viz.* ratio of stress in wood considered as a composite beam to that when timber alone is assumed to take the whole stress. This ratio is 42·4 : 335 or 0·126 : 1.

$\therefore$ S may be taken as $270\times0·126$ or 34 lbs. per sq. in. if considered as a composite beam.

(6). New Wheel,

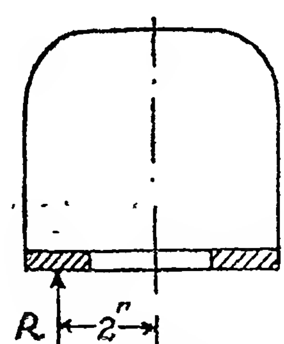


FIG. 12.

$T=R\times2=3000\times2=6000$ in. lbs.

$$S=\frac{15\times4.25+9\times5}{5\times4.25^2\times5^2}.T. \text{ (Eqn. x)}$$

$=288$ lbs. per sq. in.

This is almost the same as for existing wheel.

With a reduction ratio, as before, of stress as composite beam to the stress in timber, when considered as taking the whole stress, or 60·11 : 350 or 0·172 : 1,

$$S = 0.172 \times 288 = 49.5 \text{ lbs per sq. in.}$$

We may therefore conclude that if no deleterious effects are produced by torsion on the existing wheel, they will not be produced in the new wheel.

IV SPOKES

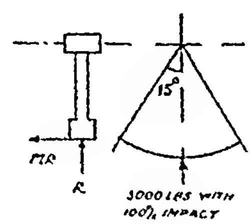


FIG 13

$$\text{Angle between spokes} = \frac{360}{12} = 30^\circ$$

$$\text{Load on each spoke} = \frac{1500}{\cos 15^\circ} = 1556 \text{ lbs.}$$

$$\text{Direct stress} = \frac{1556}{3 \times 1.5} \text{ lbs. per sq. in.}$$

$$= 346 \text{ lbs. per sq. in.}$$

$$\begin{aligned} B.M &= 21.1\ m.\ R \text{ in. lbs.} \\ &= 21.1 \times 0.3 \times 3000 \ \text{,,} \\ &= 19{,}000 \text{ in lbs.} \end{aligned}$$

$$Z = \frac{1.5 \times 3.375 \times 3.375}{6}$$

$$= 2.85 \text{ in.}$$

The bending moment will be shared by at least 2 spokes.

$\therefore$ Stress $= \dfrac{19000}{2 \times 2.85} = 3{,}220$ lbs per Sq. in. in the existing wheel.

In the new wheel, the bending moment will be about $\frac{1}{2} \times 19{,}000$ in lbs. due to broad tread bending the spoke as a beam fixed at the hub and partially fixed at the base. For a beam fixed at both ends, this bending moment will be $\frac{1}{4} \times 19{,}000$ in. lbs. Hence to allow for partial rigidity at one end, coefficient used is $\frac{2}{4}$ instead of $\frac{1}{4}$.

SUMMARY OF STRESSES.

(*100 per. cent. allowed for impact*)

(Stresses in lbs. per Sq. in.)

Design.	Stress in wood due to			Stress in steel due to	
	Shrinkage	Bending (timber alone taking the stress).	Bending (composite action)	Shrinkage	Bending
1	2	3	4	5	6
a. Existing wheel with 2¼ in. tread, when new.	3,500	335	42.4	25,000	848
b. Existing wheel after 2 in. wear in the felloe.	2,920	669	58.64	21,000	1,173
c. Proposed wheel with 5 in. tread when new.	4,582	333	60.11	37,800	1,202
d. Proposed wheel after 2 in. wear in the felloe.	6,454	1,098	75.5	27,400	1,511

Note:—The ultimate stress in teak, the wood used for felloes, is about 9,500 lbs. per sq in. It is possible that as the rim becomes smaller in diameter due to shrinkage, a small part of the shrinkage stresses may be taken by the spokes in compression, thus relieving the felloe. The stresses in col. 2, are not therefore likely to be reached. They however, give a good idea of the ultimate results.

V Effect of wheel Fixity

Case (i) When the wheels are not fixed in position, wheel *A* (fig. 14) can slide down; if it meets an obstacle making an angle greater than an angle of friction of say 30°. When this angle is less than the angle of friction, it does not matter.

whether the wheels are fixed or not, the effect being the same.

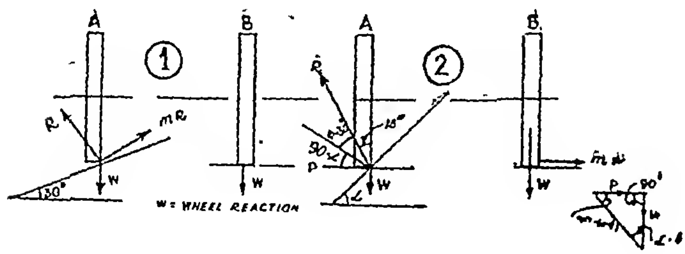


FIG 14

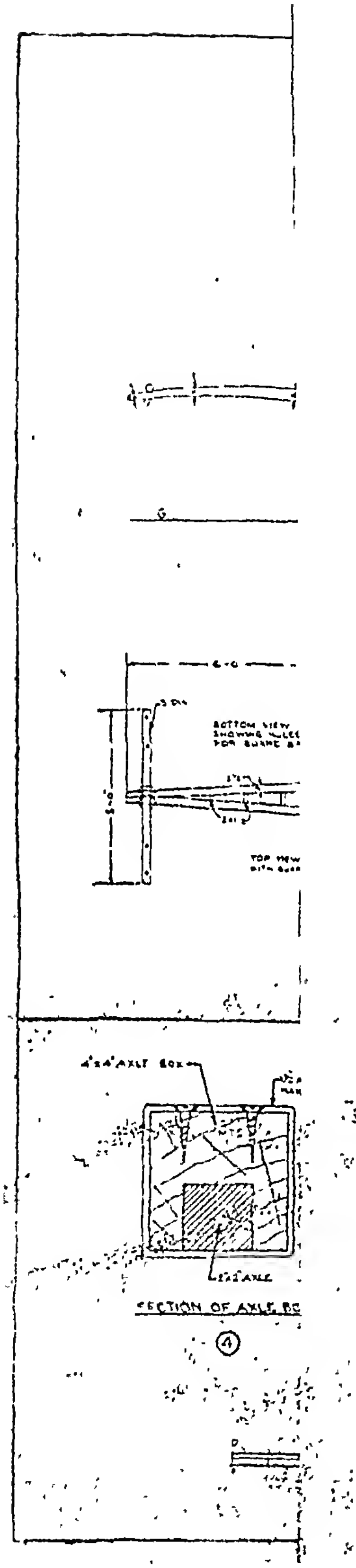
Case (ii) When the wheels are fixed, wheel A is prevented from sliding down by a force $P = mW$, the resistance offered by the wheel B, even though the angle of the wheel to the horizontal on mounting an obstruction exceeds the angle of friction. If α is the limiting angle the wheel makes with the obstruction to overcome this resistance of mW due to wheel B, then

$$P = W \tan(\alpha - \phi)$$
$$= \frac{mW}{2}$$

$$\therefore \tan(\alpha - \phi) = \frac{m}{2} = \frac{\tan\phi}{2} = \frac{0{\cdot}577}{2} \text{ with } \phi = 30^\circ$$

$$\alpha = 46^\circ \text{ approximately.}$$

The reaction R is therefore inclined to the vertical at an angle equal to or greater than 16°. It is this reaction which tends to uproot the obstacle.


4"x4" AXLE BOX
SECTION OF AXLE BO

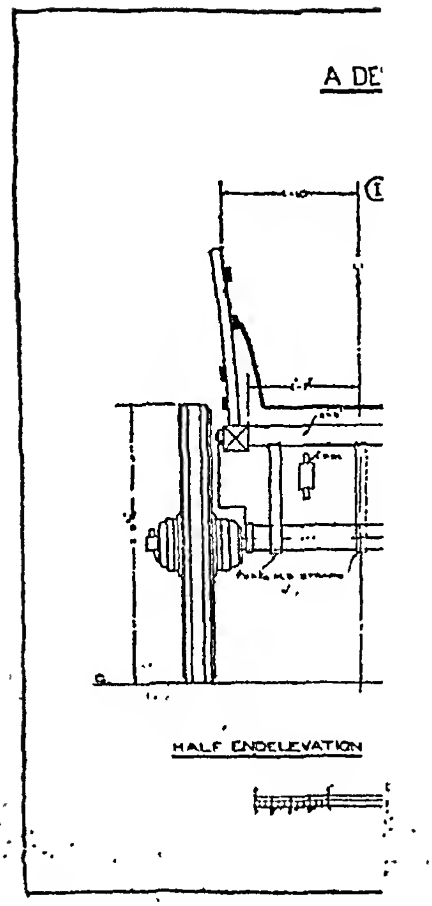
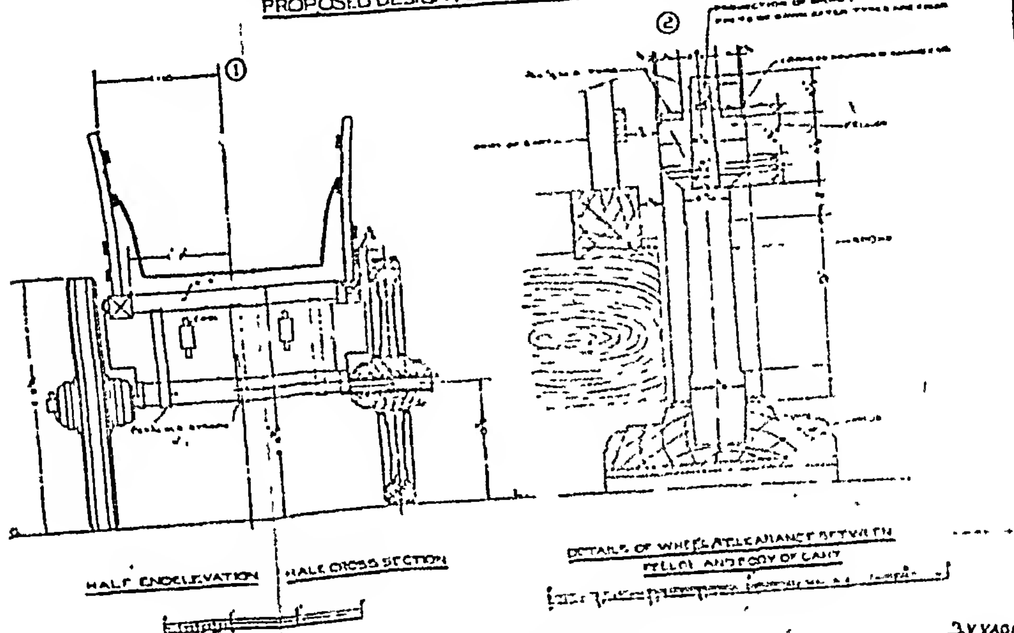

A DE
HALF ENDELEVATION

PLATE II

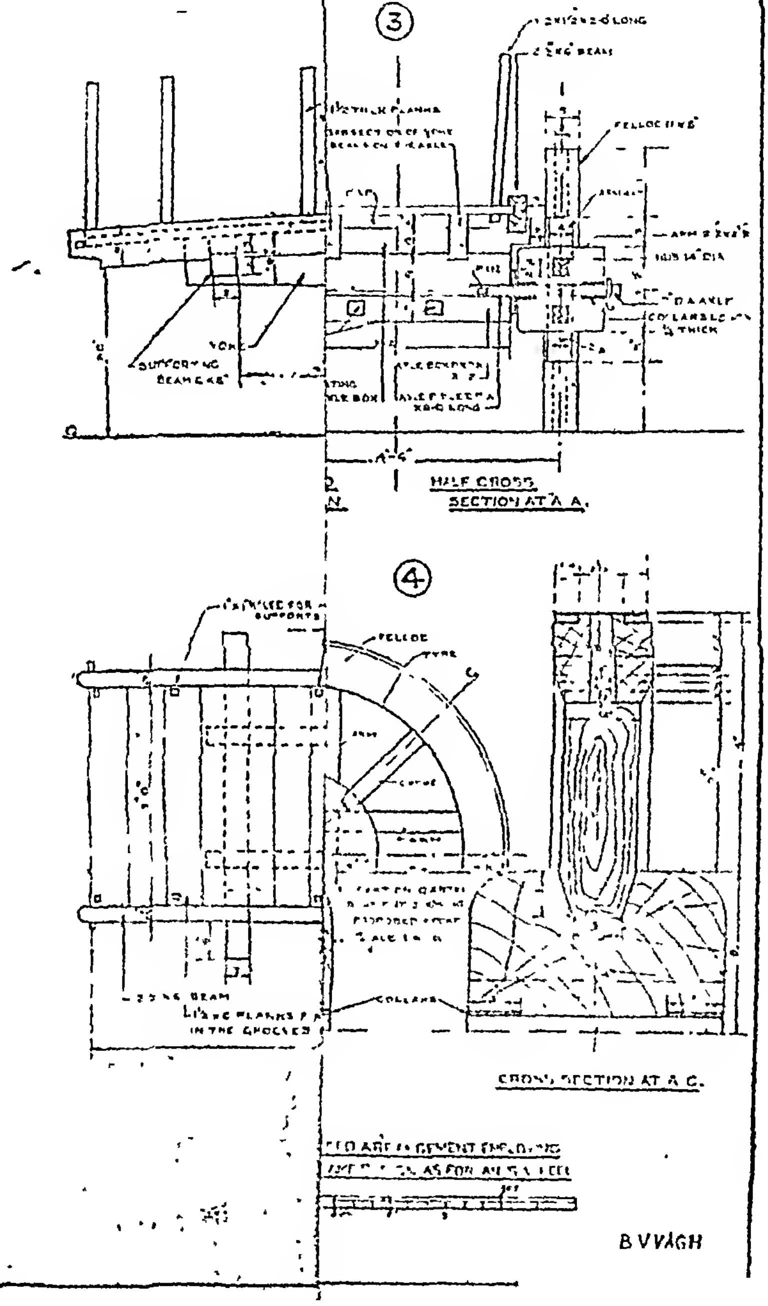
A DESIGN FOR THE WHEEL OF A BULLOCK-CART

PROPOSED DESIGN FOR AN 'S' - WHEEL



IRC PAPER No IX-101-1944.

PLATE III


③
④
HALF CROSS
SECTION AT A A.
CROSS SECTION AT A C.
FELLOE
TYRE
COLLARS
BEAM 6 X 6"
B V VAGH

PAPER NO. IX—102.

Ajoy Bridge—Failure of masonry piers—Remedial measures adopted.

By H. K. Nivas, I.S.E., Special Officer, Bihar Post-war Communications, Development, & Planning, Patna.

1. The Ajoy Bridge is on the Dumka-Jamtara road at mile 49 from Dumka (Santhal Parganas District) Bihar, and at mile 4 from Jamtara (E. I. Ry.) The Ajoy river has a very circuitous course; it takes off beyond Chakai on the border of Hazaribagh and Monghyr Districts, and flows along the southern boundary of the Santhal Parganas. The first part of its course runs through hills and forests and then it emerges into less woody and hilly country from Jamtara, finally entering the plains of Bengal, and joining the Ganges near Katwa. The catchment at the site of the bridge is fan-shaped and is 1400 sq. miles in area. The bridge is sited at a bend of the river. When in high spate the river develops high and violent waves, as much as 10 ft. high at the bends. Rock is met with at about 8 ft. below the bed.

2. **The Bridge.** The Ajoy bridge consists of 15 vents of average spans 52 ft. It was originally designed as a reinforced concrete deck bridge with masonry piers. The general arrangement of the bridge as originally designed is shown in Plate I. For economy, the bridge has been divided into four settions with thick stabilizing piers at the end of each section. The bridge has been designed for the Indian Roads Congress standard loading. The decking is 12 ft. wide. The total length of the bridge between abutments is 772 ft. 6 in. and overall length 808 ft. The decking consists of R. C. slab 7 in. thick supported on two R. C. beams, except over the crossing spans, where the slab is supported on three R. C. beams. The piers and abutments are of stone masonry with plum cement concrete hearting and have open foundations about 8 ft. below the bed, where no difficulty was encountered in obtaining a good rocky foundation. Rock was visible at the surface near the right abutment which formed a sort of a natural spur.

3. The work was taken up in November 1941. By June 1942 the substructure work was completed with the exception of the abutment at the Jamtara end. The decking could not be started for want of time.

4. **Floods of 1942 and the damage.**

There was heavy rain from the 6th to 9th August 1942. On the 8th August, Madhupur, Sareth & Deoghar gauges recorded 8 in. of rainfall each and at Asanbani, this was as high as 12 in. This heavy downpour was responsible for a heavy flood in the river with its usual high waves. On the 9th August 1942, the

High Flood Level was 475.52, about 4½ ft. higher than the assumed High Flood Level. As the bridge is sited at a bend of the river, the main current was at the outer bank, namely the Jamtara end. It deflected towards the centre of the bridge cutting the sheltered water, thus forming strong whirl-pools with the result that pier No. 15 was thrown towards the left bank, pier Nos. 10, 11 and 13 were thrown towards the right bank and also down-stream. Pier No. 8 a thin pier, which was at the mid-stream, was not damaged. Pier No. 6 was thrown over to the north side and pier No. 4 to the south side. These six piers were overturned at different levels: Nos. 10, 11, 13 and 15 at the level of the supporting foundation block; No. 6 one course above the foundation block and No. 4 three courses above the foundation block. The approach bank behind the right abutment was severely eroded and a large quantity of sand deposited in the bed of the river near the left bank. Photographs A, B & C show the damage to the bridge. Pier No. 2 was dismantled and removed, as all the thin piers were to be replaced. Photograph C shows a part of the centering of R.C. decking between left abutment and Pier No. 15.

5. Possible causes of the damage.

(a) The assumed H.F.L. on which the bridge was designed was exceeded by over 4 ft. which brought the flood well over the cap of the piers. Had the superstructure been constructed, this high flood would have submerged the greater part of the haunches of the supporting beams of the bridge deck, leaving only a free board of a few inches at the centre.

The Highest Flood Level was fixed by the river sectional method, for the catchment area of 1400 sq. miles, with a run-off factor of 900 against the normal 825. No allowance was made for the curved flow of the river at the bend at which the bridge was sited. It is found in this case that a run-off factor of 1,000 is very appropriate, as this brings the H.F.L., very much closer to the actual H.F.L., making due allowance for the curved flow.

(b) For economy, the R.C. superstructure had been designed as 4 independent sections to admit of temperature variations and for this purpose there were central stabilising piers and end supporting piers of heavier section than that of the intermediate supporting piers (Plate I). The special heavy section piers withstood the flood; all the thinner intermediate piers but two, collapsed.

(c) Bridge piers are ordinarily designed to withstand the force of a flood in their longitudinal direction of straight-flowing currents approaching and leaving the bridge. Unless the bridge is a skew one, this would result in piers being built at right angles to

the bridge deck as was the case in this bridge. The trouble in the case of this bridge was, however, that it was sited on a curve of the river, and the flood water did not flow in a straight current but was thrown from one bank of the river to the other with the result that only the heavier section piers could withstand the water thrust.

(d) The cross currents formed by the curved bed of the river augmented by water spilling across the country over one bank, added to the abnormal flood level and accounted for the collapse; they were overturned at or near the level of the foundation blocks which built up to the rock in the bed of the river. There was no settlement in the foundations nor was there any damage to them.

(e) The damage to the piers was also partly due to the type of piers adopted for this particular siting. Due to the bend, non-axial flow was to be expected bringing about side pressure on the piers. The thicker central stabilising and end supporting piers withstood the flood but the thinner intermediate piers failed because they were too thin to resist unbalanced side pressure for which they were not designed. Ordinarily piers are made thick, but the contractors in their endeavour to economise made a special design by dividing up the bridge into sections having thin and thick piers.

(f) It might be said that had the superstructure been constructed before the floods, its weight would have prevented the piers from collapsing. This assumption is, however, not correct. The superstructure would have simply rested over these piers and with its roller bearing contacts, its weight could not have helped the piers to resist the side pressure. In fact, with the flood submerging a part of the beamwork of the superstructure, a lot of vibrations would have been set up, resulting even in an earlier collapse of the piers.

(g) The outcrop of rock on the right side which acted as a spur was also a contributing factor in deflecting the current to the centre, (which portion has now been cut and removed).

6. **Remedial measures.** The H. F. L. recorded in August 1942, which was responsible for the collapse of the piers, can be taken as the basis for the new design. About 3 ft. free-board had been allowed for in the redesign of the bridge when taking the old H.F.L. It was considered that a further raising of the bridge superstructure by about 3 ft. should meet all future contingencies. The best way of dealing with the slim piers, all of which had collapsed except two, was to replace them by twin R.C. columns of about 3 ft. dia. each, resting on R.C. bases over the existing masonry foundation blocks and connected rigidly to the R.C. bridge superstructure with one or two R.C. stays running across the columns at midcentre. In this way the whole bridge would be rendered more rigid and at the same time the columns would offer little resistance to the flow of cross currents. The

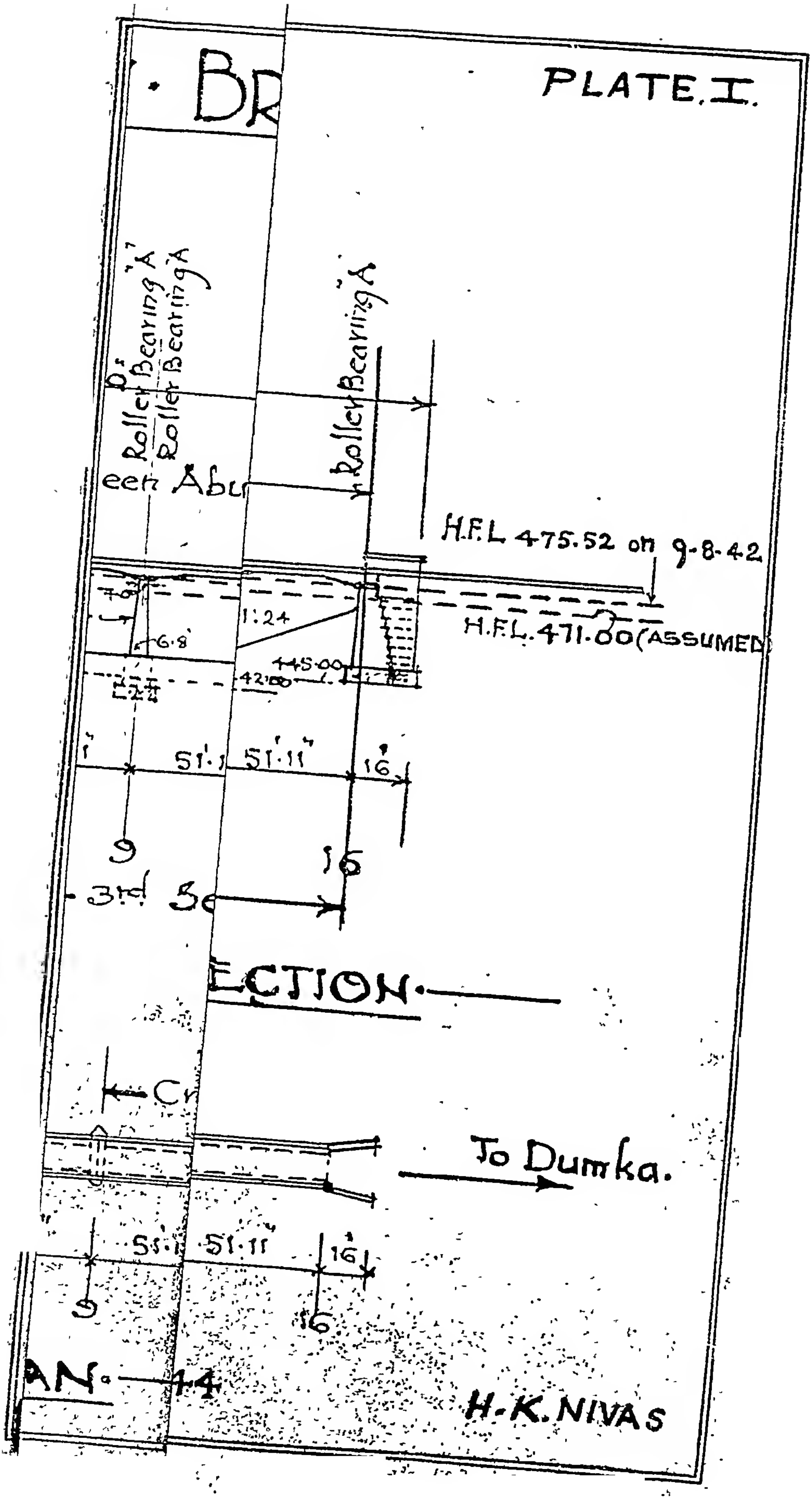
only objection to this construction was that the piers must be completed along with the bridge-deck superstructure, i. e. to all intents and purposes, the bridge must be completed before the next rains. Without the superstructure in place to tie them up, the R.C columns would have no stability since they could not be secured rigidly to the foundation masonry. The completion of the bridge by the next rains would not have been a difficult problem in normal times, but due to the war there was uncertainty of getting M.S. reinforcement and cement, it was practically impossible to complete the bridge in time. The alternative was to suspend work after completing the heavy piers and the two abutments, leaving the R.C. column piers and superstructure to be completed after the war, but this would have led to heavy claims. Another alternative was to replace the slim piers by other masonry piers of heavier section. This would have necessitated the widening of foundations which had already been sunk down to rock 8 ft. or so below the bed, which would have made the cost excessive.

7. It was, therefore, decided to adopt the first alternative of constructing R.C. columns resting on R.C. bases over the existing masonry foundation block and to complete the bridge by sections, i.e. stabilising pier after pier. Several types of R.C. columns were considered and the one that was considered suitable and was adopted is shown in Plate II. These columns were designed to withstand the tractive force, temperature effects and pressure of current acting at an angle of 55° to the Pier axis. The design of R.C. columns in the crossing spans is shown in Plate III.

8. After completing the design work and the preliminaries the work was restarted in March 1943 and completed on 20th June 1944. Only one section was completed by 1943 floods. Photograph 'D' shows the completed bridge which has withstood the 1944 flood.

9. With the completion of this bridge and other minor bridges an important road has been opened up. This road has been classed as a Provincial Highway in the Post-war Road Development Scheme and joins the Grand Trunk Road near Barakar in Bengal.

10. Cost. The original cost of the bridge was 1,33,300/- The total cost of the completed bridge including the loss comes to Rs 1,55,600/. excluding Land Acquisition and cost of approaches, and Rs. 2,00,000/- including these. The loss due to the collapse of the piers and construction of new piers etc., works out to Rs. 30,600 - including Rs. 8,900/- paid as compensation to the contractors for the delay in completion due to the failure of the piers. The cost of the bridge per running foot excluding the loss is Rs. 190/- with a roadway of 18 ft. over 10 spans and 16 ft. over three crossing spans.



BR
PLATE. I.
Roller Bearing "A"
Roller Bearing A
Roller Bearing "A"
een Abu
H.F.L. 475.52 on 9-8-42
H.F.L. 471.00 (ASSUMED)
1:24
6.8
445.00
42.00
51.1
51.11
16
9
16
3rd
ECTION
Cr
To Dumka.
51.1
51.11
16
9
16
AN.
44
H.K. NIVAS

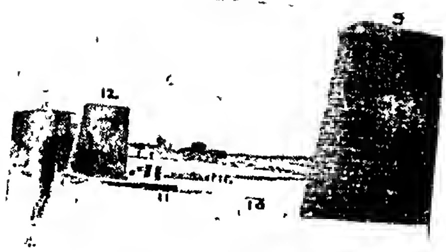


Fig. A

Fig. B

Two views of the Bridge after the failure of piers. Note the bend in the river course.

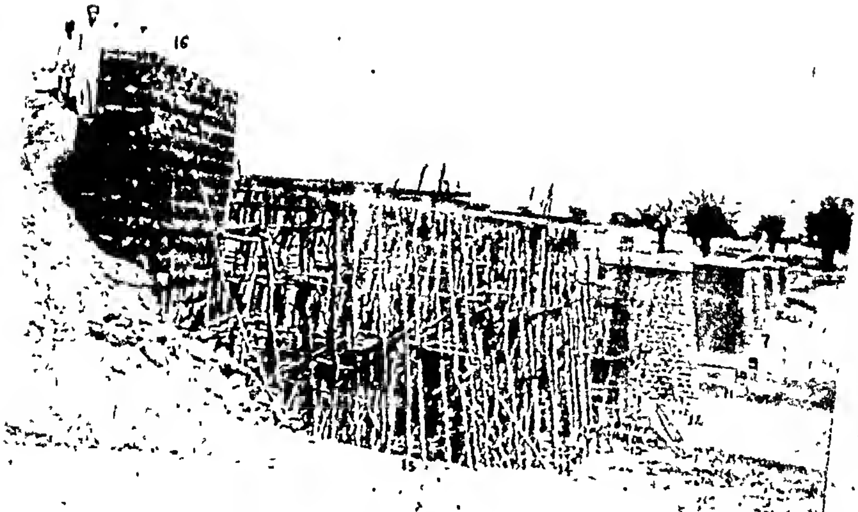


Fig. C

Showing the centering for decking the end span and the R. C. [illegible] for 13th pier. Foundations of missing piers are [illegible]

I. PROCEEDINGS OF THE NINTH SESSION OF THE INDIAN ROADS CONGRESS

Vol. IX. Part 3. MADRAS February 1945.

1. PRESIDENTIAL ADDRESS

The Ninth Session of the Indian Roads Congress was held at Madras from the 6th to 13th February, and was formally opened by His Excellency, Sir Arthur Hope, G.C.I.E., M.C., the Governor of Madras, at 11-0 A.M. on the 7th February 1945. In requesting His Excellency to open the session, Mr J. Vesugar, the President, delivered the following address :

YOUR EXCELLENCY AND GENTLEMEN :

The Indian Roads Congress is most grateful to Your Excellency for coming here today to open this, the ninth session of the Congress. We are particularly pleased to be meeting in your Presidency because a notion prevails, and not without some foundation, that we in Delhi tend to think in terms of Northern India. But what geography has perhaps made inevitable, we should try and correct, the more so since centrifugal forces seem to be in the ascendant today. Whatever may be the political advantages of devolution of authority, there is no gainsaying the fact that no profit will accrue—indeed all might be lost—by adopting a policy of economic, intellectual, or spiritual isolation. If this is true when applied to contacts between India and the United Kingdom, the New World and the Old, East and West, how much more truly the maxim applies to India itself. We have become so accustomed to describing the country as a "vast continent", that a purely relative statement has come to be accepted as a fact. But compared with many other lands, India is by no means vast—that is in area. There is a danger, though, that just at the time when rapid communications are in effect reducing the size of even large countries, we in India will annul this effect by emphasising the units rather than the country as a whole. We are therefore most appreciative of the privilege of meeting in your capital, the southernmost in India, and thus having the opportunity of correcting our perspective.

2. To your Government also we would like to extend our warm thanks. We know that owing to the exigencies of war, not only have you many serious preoccupations, but that shortage of accommodation and supplies renders the reception of a Congress of this size a formidable problem. That you have overcome the difficulties in a munificent spirit, puts us doubly in your debt because I see from the interesting programme you have arranged that you have also provided more than ample food for thought.

3. Though we shall be discussing many technical matters at this Session, we have, I think you will agree, arrived at a stage when the influence of the Congress should be felt in the larger non-technical sphere. As our President said at [illegible] "We claim, and I think with justification, to know more about roads, [illegible] possibilities, and what is wrong with them than any other body of men [illegible] there are times such as the present when we are entitled to say, and

fraction of the cultivable area. Therefore the solution is a multitude of wells and pumps. The next most important requirement is to make good the nitrogen deficiency and plans are in hand for the manufacture of three hundred and fifty thousand tons of ammonium sulphate. Considerable though this quantity may be to produce and distribute, the ultimate requirement is thirty times this amount. Again, improved seed raised by Government is to be farmed out for propagation to A-grade growers and from them, for mass production, to B-grade farmers. At each stage the seed has to be inspected, rogued, sorted, and assigned. Finally it is to be distributed to sixty million farmers in six hundred thousand villages. With the largest cattle population in the world the extent of work required for improved animal husbandry and dairy farming may well be imagined. But amongst our ignorant peasantry, none of these improvements would progress very far without what is called extension work. It is estimated that as many as four hundred thousand village guides, twenty thousand fieldmen, twenty thousand stockmen, fifteen thousand non-graduate assistants, and hundreds of officers will be labouring on these imperative tasks. How is the peasant going to instal and run pumps, how is the fertiliser and seed distribution and extension work to proceed, how are the seed and potato stores, grain silos, cold storage facilities, distribution centres and markets to function without a fine network of all-weather rural roads?

10. Plans for other nation-building activities are under preparation—for forests, for fisheries, for cottage industries, for rural electrification, and so on. All are dependant on a good system of road communications. Further, during the process of road construction money will be spent in the very quarters where it is most desirable. During an official inquiry by the United States Congress, it came to light that eighty-one per cent of the expenditure incurred on roads went to employment—twenty-nine per cent on direct employment on the road and the balance, fifty-two per cent on labour employed in producing and transporting the materials of construction. In estimating figures for India, I find that almost ninety per cent of the total expenditure on roads will ultimately go to wage-earners.

11. To set our youth free, to widen the outlook of our villagers, we shall need bicycles, motor cycles, motor vehicles. If a reliable motor cycle were made and sold in India for three hundred rupees, and this is not impossible, imagine the effect it would have in making the village youth and the village *lohar* machine-minded. He would be all the more ready for pumps, machines, rural electrification and rural industries. All talk of establishing a thriving automobile industry in India is futile unless we can visualise a very considerable increase in the number of motor vehicles in commission. And that in its turn means more and better roads. Indeed it has been calculated that, broadly speaking, the value of a country's investment in motor vehicles is about equal to its investment in roads. So far as better roads are concerned, it has been estimated that if thirty-five motor trucks or buses traverse every day a mile of good, instead of *kutcha* road, the saving in petrol, oil, tyres and repairs which would accrue would provide sufficient funds to amortise a loan for building a mile of concrete road. When three hundred thousand motor vehicles are using such roads the saving would equal the amortisation charges of the entire Nagpur plan.

12. We may well ask ourselves: How is it so much misapprehension exists, and what steps are being taken to inform the public of the realities of the situation? To my mind it is of utmost importance we probe these questions because not only is it recognised on all sides how desirable it is to carry lay opinion, but the present war has demonstrated, if demonstration were needed, that there is no place in the modern world for an undeveloped hinterland. Survival in the future may depend on the recognition that every village is, if not a potential front line, at least a link which if weak may endanger the whole chain of national defence. And by a weak link I mean any unit whose resources in man-power and material have not been developed to capacity. This is no fanciful picture. Surely we are today suffering sufficiently from our lack of vision not to want to repeat the experience. Let us remember: "To choose time is to save time".

13. An answer to the question I have put, I would like to suggest to you, is contained in the thought provoking presidential address of Dr. David Anderson, delivered to the Institution of Civil Engineers in November, 1943. He said: "For one reason or another—although the work that is being carried out by modern engineers is even more exacting than in the past, often on a much larger scale, and certainly far more complicated—civil engineers and the heavy responsibilities they carry are largely ignored by the modern layman. It does not seem to be realised that if engineers failed in their work modern life as we know it would break down". Dr. Anderson went on to say it was disturbing that the services of engineers were apt not to be made use of in the early stages of schemes. "It may be", he said, "that engineers are largely responsible for this state of affairs. They are prone to be reticent and to shun self-advertisement. It is apparently not realised that engineers are planners as well as technicians, and that the success that attends modern engineering work is due not only to technical skill but also to the very careful study made beforehand of all the conditions, and to the sequence of operations that must be followed." Dr. Anderson then declared: "It is high time that the engineer who has perhaps rashly and blindly created modern life, should now be associated with the control of it and help in directing its future shape."

14. So far as we in India are concerned, we have yet to find an engineer in any position of national consequence. To Lord Reith, who overcame the disability of being an engineer to become a public figure, we extend a warm welcome. As you know, he is leading a mission to the Dominions and India to discuss with the Governments concerned the future organisation of the tele-communication services of the Commonwealth. Though it is no part of his mission, let us hope that its very nature will enable Lord Reith to do for Indian communications what Professor A.V. Hill did for Indian science.

15. Much as we need whatever assistance can come to us rom outside, there is no question that any enduring help must come from within. To secure this I commend for your consideration the appointment of a small sub-committee of the Congress to examine the available means of publicity, official and non-official, the extent to which they are being availed of, and the possibilities of increasing road education. To many this course may be distasteful, but whether we like it or not we must realise that propaganda has come to stay. For some years the railways in India have carried out praiseworthy publicity campaigns within the country and abroad. Railways are commercial undertakings and therefore concerned with showing an increase in receipts over expenditure. Because roads are regarded as "free" and supplied by some governmental authority, they are apt to be accorded the familiarity—and one might almost say contempt—associated with all "free gifts".

16. I would, however, like to put it to you that this entire concept is wrong. One may not buy an actual ticket to entitle one to use a road, but the issue of quarterly registration slips which are borne on windshields, the tax on vehicles, tyres and parts, and especially the tax on petrol are only indirect ways of ticket selling. It has been said, especially in connection with road-rail competition, that whilst a capital of eight hundred crores has been invested in railways, the permanent way is provided free to the motor user. But let us remember the motorist has paid more in taxes than has been spent on roads since motor vehicles became general. What he has paid up till now, together with the capital invested in motor vehicles and motor transport, already equals half the capital invested in railways; in ten years' time this sum may be expected to surpass railway investment by a considerable margin.

17. We come now to the vexed question of the petrol tax. If this were ploughed back into roads, there would of course not be the same objection to the burden. No country taxes motor transport as high as India, and in the majority of progressive countries most of the receipts go back into roads. But it is averred that this is a revenue tax, and that it is against financial

canons to hypothecate a certain tax for a specified purpose. Petrol is taxed higher, *ad valorem*, than any other commodity—higher than luxuries such as whisky, cosmetics, cigars, diamonds, golf balls, or silks; by the gallon it is taxed as mush as beer. Surely it is inequitable that such a crippling burden should be imposed on motor transport just because the petrol tax is an easy device for collecting revenue ?

18. At this point may I draw your attention to the present emphasis—in my view, over-emphasis—on transport. In Delhi within the last four weeks there have been two conferences of far-reaching importance to road development. One was a meeting of the Transport Advisory Council and the other of the Policy Committee on Transport. Though the fate of road expansion was largely decided at these two meetings, the Indian Roads Congress, the one association of road experts in India, was not represented. Such members of this body as were present were there in their capacity as officers representing definite sectional interests. The road issue was clouded by transport matters and the accent was on control instead of expansion. No road engineer denies the need of regulation of motor transport, but one cannot over-stress the desirability of keeping the question correctly focussed. To illustrate, I would like to point out that India in spite of its size and vast numbers, has a smaller number of motor vehicles than New Zealand with a population equal to that of Calcutta. On the other hand, if one looks at a railway map of the world, there are only three areas where there is fine network of lines. One of these areas is India. Now the time has come when Indian roads should also find a place on the world map.

19. When we made our recommendation for a Road Board at our last session in Gwalior, a recommendation which was later endorsed by the Chief Engineers at Nagpur and by the Technical Committee on Transport, we had a definite object in mind. The outcome of these recommendations has been if I may invert Shakespeare that we have been given the name without the deed. Whilst we welcome the Departmental Committee, which will be called the Road Board, as a rational method of eliminating unnecessary procedure, we are emphatically of the opinion—and I feel sure I am voicing the opinion of you all—that it cannot achieve the fundamental purpose for which a Road Board was recommended.

20. But our disappointment must not prevent us from appreciating the great contribution made by the Central Government in taking over responsibility for National Highways and Trails. In the process, the accent has now shifted from rural roads to highways. There is some danger in this, at least until provincial liabilities have been finally pegged down. For, if retrenchment should once again be the mode, those district communications which are most required for nation-building purposes will be the first to be sacrificed. On the other hand, the danger to the main highways, national or provincial, is not so great; there will always be an influential section to press for these communications if they are deficient. At the same time, there should be no delay in establishing the lines of these main highways. Land should be acquired, all earthwork finished, base coat provided and all ordinary bridging completed. In other words, the aim should be to bring these roads to a stage when they provide year-round communication, postponing, if need be, the building of the permanent road crust.

21. Briefly our present position is this. What with the Scylla of finance on the one side and the Charybdis of the constitution on the other, our barque is sticking on the shoals. In its bare essence the problem boils down to the inability of the Provinces to find the money for the necessary road programme from the inelastic sources of revenue open to them. The Central Government, for its part, contends that the present division of revenue was carefully considered when responsibility was divided. But that was over ten years ago. Are six years of war to make no difference to our outlook ? When are we

going to wake up and realise that the horse and buggy era, when a day's radius was twelve miles, has gone for ever? The Government of India Act, we are told, cannot be modified piecemeal. Nevertheless, accepting that proposition, is that not all the more reason why we should line up in time for the new constitution? Let us be ready with an authoritative recommendation before the curtain goes up.

22. The time for generalities is long past. If we are to be ready for the new order we must be prepared for new ideas. One such idea would be to create a National Road Trust, representative of the Centre, Provinces and States, with authority over the country's entire road system. Succeeding to the revenues collected from taxpayers in their capacity as road users, the Trust—as qualified custodians of the national interest—would allocate these funds in a manner most conducive to this end. Assured of steadily increasing assets, the Trust might be allowed to borrow the funds necessary for the Development Plan. It may be empowered to raise a loan of, let us say, four hundred-and-fifty crores in fifteen years. A specified portion of this may be a permanent debt; expanding road revenues would meet the interest and redeem the balance. The implications of such a proposal are obviously far-reaching and their investigation is a task for an authoritative and impartial Commission. If the Commission's conclusions are in favour of the creation of a National Road Trust, it might draft and recommend an instrument of instructions. On the other hand it might make radically different recommendations.

23. These suggestions are made with the idea of provoking discussion. You may reject them out of hand. But there is not one of us who does not realise the paramount necessity—to quote a phrase of Churchill's—"of leaving no wire unpulled, no stone unturned, no cutlet uncooked"—to pull our barque off the shoals and be ready with our charts for the open sea. As His Excellency the Viceroy said last month: "The great thing is to get something moving as soon as possible, since the problem of communications seems to me to be the whole basis of India's social and economic advance, which we are all so anxious to forward". Your Excellency and Gentlemen, may I suggest that the keynote to our discussions should be "Get something moving—forward".

* * *

May I now request Your Excellency to be so good as to open this, the Ninth Session of the Indian Roads Congress?

In declaring the Session open, His Excellency said:—

Mr. Vesugar and Gentlemen,

I should like to say first of all how much pleasure it gives me to respond to your invitation to open this Congress. I am indeed glad that your Congress is meeting for the first time in its history in Madras, and on behalf of my Government and myself, I have the greatest pleasure in welcoming all of you to our capital city and to our Province.

Kipling once in an unkind moment described Madras as "a withered beldame now". We do not admit the charge, but in so far as the wrinkles on the face of Madras consist of ruts in our roads, you will, I hope, see something of what we are doing to give some rejuvenating treatment.

Our climate too, has been equally maligned, and described as "three months hot and nine months hotter". Here again we refute the impeachment and contend that our climate is no warmer than the welcome which we extend to you today.

After the very full analysis of the road problem of India which has been given by your President in the speech to which we have just listened, I do not think I need dilate at length upon the general question. I am sure everyone, whether he be a technical road engineer, or a layman, will agree entirely with your President's estimate of the supreme importance of roads for the development of India. As he has said, practically all forms of development, not merely in agriculture, animal husbandry and industry, but even in such apparently unrelated matters as education and public health, depend more or less directly upon communications. I may say without fear of contradiction that communications by road and rail are the arteries through which flows the life-blood of any modern state and without them we should starve and die.

I should like for a few moments to tell you something of the road system of this Province, and of our organization for maintaining it, as well as our plans for road development which are, we believe, in essentials on the lines recommended by the Nagpur Conference to which your President has referred.

We have in the Province over 25,000 miles of surfaced roads and 14,800 miles of earth roads.

Until very recently all these roads, except for a few ghat roads to Hill stations, were under the control of local bodies, municipal councils and district boards, who maintained them partly from their own resources and partly from Government grants. One substantial source of income of local bodies was the tolls levied on all vehicles both motor vehicles and bullock-carts. In 1931 these tolls were abolished and a tax on motor vehicles alone was substituted, the proceeds of which were to be distributed to local bodies up to the amount previously raised from tolls. Unfortunately collections from the motor vehicles tax failed to come up to expectations and in fact have never been equal to the revenue formerly raised from tolls. This diminution in the income of local bodies, which coincided with a period of acute financial stringency when the Government were unable to help local bodies, was undoubtedly one of the chief factors in the progressive deterioration in our roads.

On the administrative side efforts have been made with some success to increase efficiency by provincialising all posts of District Board Engineers in 1924 and of District Board Assistant Engineers in 1939. I am glad to see that one of the members of your Council, Sir Kenneth Mitchell, considers that in this respect Madras is ahead of some provinces.

With the coming of war conditions, Madras has become successively a possible theatre of operations, and a base for mounting the offensive against Japan. The large influx of troops, and the imperative need for speedy improvement in our roads, necessitated taking over long stretches of road from the control of local bodies. At present we have two special road-circles under the P. W. D. dealing with the upgrading and maintenance of 2,650 miles of roads of strategic importance. You will see something of their work on your road inspections near Madras. At the same time increased grants have been given to local bodies to help to meet the increased cost of maintaining the roads still under their control.

Planning for the future has not been forgotten despite the pressing needs of the present. Our post-war plans provide for a road system which is generally in accordance with the standards proposed by the Conference of Chief Engineers at Nagpur. We have, however, felt unable to accept the recommendations of that Conference for normal and minimum land widths for National and Provincial Highways. The acceptance of these standards in full would throw large areas of land out of cultivation, and involve pulling down large numbers of road-side houses. They would also increase the cost of road construction so much that it might become impossible to finance other desirable improvements. This objection does not, however, apply to the proposed widths of made road. Indeed, in the case of village roads, we consider that the standard of desirable width proposed by the Chief Engineers' Conference should be raised from 16 to 18 feet to allow two loaded hay carts to pass each other,

My Government have for some time been considering the question of taking important lines of communications directly under Government control. A special officer, Mr. Dogra, was appointed in December 1943 to draft a scheme for the purpose. His proposals involve the formation of a Highways Department to maintain the more important roads, and are at present under consideration as part of our plans for Post-War Development.

I am glad that your President has stressed the need for attaching proper importance to the improvement of village roads. My Government entirely agree with his view that for the improvements of national welfare there should be a balanced development of different classes of roads and that it should proceed in a planned sequence. Our programme of post-war road development provides accordingly for a total milage of over 56,000 miles of road. This includes 22,000 miles of village roads of which over 13,000 miles are to be newly constructed and the balance are existing roads to be improved. My Government are considering a proposal that these new village roads should be constructed by Government at their cost and handed over to local bodies for maintenance. We realise that local bodies cannot undertake such large commitments without additional resources, and are considering proposals, which we hope to announce shortly, for placing sufficient resources at their disposal.

In the execution of our post-war road development scheme we intend to employ as many demobilized soldiers as possible. Our plans will require a more or less permanent staff of 1,800 drivers and about 1,000 skilled workmen such as Sappers and Miners, in addition to about 3,600 unskilled men who will be needed for some years. We hope also to provide posts in the new Highways Department for suitable N. C. O.s who will work as supervisors.

I have given this account of our failures and our successes, of our hopes and our plans, in the belief that you will find it of practical interest. We do not claim to have reached perfection, but we do hope that we are progressing in the right direction.

Finally, Gentlemen, I welcome you once again to Madras, and trust that you will find your stay profitable and enjoyable. I hope that before your Congress meets again, you may be able to turn your talents to the needs of peace with as much success as you have applied them to the needs of the war.

Mr. Vesugar, in thanking His Excellency for his encouraging and inspiring address, requested him to present on behalf of the Indian Roads Congress, the Congress Medal to Mr. V. N. Rangaswamy of Burmah Shell, Madras, for the best essay on the subject of "Improving the Technical Education of Road Engineers".

2. BUSINESS MEETING

The general business meeting of members was held on Saturday the 10th February 1945 at 10-30 A.M., with Mr. Vesugar in the chair. In all 136 members (names and particulars in Annexure I,* pages 27-28), attended. This was the biggest meeting in the history of the Society.

2. The minutes of the last (Eighth) Business Meeting, the Report of the Council for the year 1943-44 and the Audit Report* for the year 1942-43 were received and approved.

3. The meeting then proceeded to elect members of the Society to serve on the Council until the next General Meeting. (List printed on page (i)).

4. The following business was also transacted :—

(i) The meeting, all Members standing, recorded with special regret the deaths of the following Members† of the Society, during the year 1943-44 :—

(ii) The following resolutions were moved from the Chair and passed :—

(a) The Indian Roads Congress expresses its thanks to the Government of Madras for inviting the Congress to hold its General Session in this city, and for the efficient arrangements made.

(b) The Congress expresses its thanks to His Excellency the Governor of Madras for kindly opening the Session, and giving permission to print his encouraging address in the proceedings.

(c) The Congress wishes in particular to convey its gratitude to Mr. H. R. Dogra, Chief Engineer, Communications, Mr. P. A. Krishnaswamy, the Local Organizing Secretary, and the members of the Local Committee for the excellent arrangements made for the convenience of members attending the session.

(d) The Congress expresses its thanks to the Corporation of Madras, the Commissioner, and the Corporation Engineer (Mr. K. K. Nambiar) for kindly placing their buildings at the disposal of the Congress, for the arrangements made for the inspection of the Waterworks, Kilpauk, the Corporation Emulsifying plant and other interesting engineering works, and for entertaining the delegates to tea.

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* See pages 13 to 26. † List on page 16.

(e) The Congress expresses its thanks to the Public Works Department, Madras, and Rao Bahadur P. V. Raju, for showing the delegates round some most interesting works and for entertaining the delegates to tea.

(f) The Congress expresses its thanks to the Indian Roads Transport and Development Association for their "At Home" to the Members.

(iii) **Venue for the next Session.** The President announced that the States of Udaipur and Jaipur had kindly extended, through their official delegates, invitations to the Congress to hold the next General Meeting in their States. Kalingpong and Karachi were also suggested as possible venues, the former because of the interesting hill road development contemplated in the vicinity. It was decided to leave the final selection of the venue for the next session to the Council.

(iv) Mr. H. E. Ormerod moved the following resolutions :—

(a) "The Council should consider previous resolutions of the Congress and the Council, and other pending matters of importance, and decide what action if any is required to implement them".

(b) The Indian Roads Congress should adopt a **CODE OF HIGHWAY SAFETY** based on the recommendations of The British Road Federation as contained in their printed report entitled "Roads and Roads Transport, 1944" with such modifications and additions as may be considered necessary for India, and that a Sub-committee should be appointed to prepare a draft of the proposed Highway Safety Code at the earliest possible date, for submission to the Council.

After some discussion, the questions raised were left to the new Council for consideration, with a suggestion that a Sub-committee should be appointed to prepare a "Highway Safety Code".

(v) The attention of the members was called to the recommendation recorded in paragraph 13 (*iii*) of the minutes of the 20th meeting of the Council that members of the Society co-opted to the Council should have full voting powers. This was accepted.

5. Then followed a general discussion on several points raised by Members at the meeting. The Council, on behalf of the General Body, undertook to consider suggestions that members should be supplied with badges displaying their names and the interest they represent ; it is desirable to post a list of members attending the

session at the door of future meeting halls; that volunteers should be deputed to act as guides and information officers at the hotels where large number of members are staying; and that other efforts should be made at future meetings to render greater service than has been done in the past for the convenience of members. The President promised that the Council would consider these matters but he pointed out that owing to war time restrictions and difficulties, it had not been possible to make as good arrangements with regard to transport, and the housing of members close together, as would have been the case in normal times. In his own opinion, the arrangements made under very difficult conditions were very good and deserving of the thanks of members.

6. Other suggestions made to the Council by the General Body were the desirability of securing a representation of the Congress on the Government of India Policy Committee No. III A on Transport and the necessity for the early setting up of Sub-committees to give advice on Specifications and to draft recommendations to the Central and Provincial Governments in the matter of provincializing the District Board Engineering staff.

7. At the suggestion of a Member, the President called for a general discussion on the Engineering works inspected during the last two days. The local members answered many questions.

The General Meeting then concluded.

3. REPORT OF THE COUNCIL TO THE GENERAL BODY OF MEMBERS AND AUDIT REPORT.

A. Report of the Council for the period 1st October 1943 to 30th September 1944

GENERAL

Owing to the war situation, the Indian Roads Congress, like all other scientific institutions, had to curtail its activities and did not hold a full session for nearly 4 years, from December 1939 to October 1934. As the situation has now improved and there is prospect of an early and successful termination of hostilities, at least in the West, the activities of the Society have been revived, in spite of the continuing preoccupation of most of its members with war work.

A full session of the Society was held in October 1943 at Gwalior, when as many as 100 members attended. This session was a momentous one in the history of the Society, as it was then that the Congress made concrete and practical recommendations to the Government of India on post-war road development. As a consequence of these recommendations, a Conference of Chief Engineers was called at Nagpur in December 1943 by the Government of India. The Report of this Conference, now known as the Nagpur Report, recommends the construction or improvement of a network of 400,000 miles of roads (to be completed in the First ten-year period after the war) as the minimum requirements of the country in the next 20 years, and estimates the cost at Rs. 450/- crores.

The Congress has since given considerable impetus to the examination of the recommendations contained in the Report by submitting to the Central and Provincial Governments the considered suggestions of its Council which met twice after the full session at Gwalior, first at Bombay in March 1944, and then at Lucknow in September 1944.

2. ADMINISTRTAION

During the period under report, Mr. J. Vesugar, at present Industrial Adviser to the Government of India, held office as President. Mr. G.M. McKelvie has been Honorary Treasurer from the 29th December 1943, when he assumed charge as Consulting Engineer (Roads). Mr. K. S. Raghavachary continued as Honorary Secretary throughout the year.

In view of the important part the Society has had to take in planning for post-war road reconstruction and because of the need for quick decisions, the President suggested that an Executive Committee consisting of the office-bearers should be appointed to deal

with urgent business on behalf of the Council and, in January 1944, in anticipation of the approval of the Council he appointed such a committee to deal with certain proposals which were to be put to the Government of India. His action was approved by the Council at its 20th meeting at Bombay and a regular Executive Committee consisting of the office-bearers of the Council was then appointed. The Executive Committee met three times during the year to transact urgent business.

. At its Bombay meeting also, the Council authorised the Executive Committee to appoint an Assistant Secretary and to pay for such assistance and help as the Secretary might require in carrying out the business of the Congress. After advertisement, Mr. Rishi Raj was selected for the post of an Assistant Secretary on Rs. 400-20-600 per mensem and he took up his duties on 5-6-1944, but resigned on the 1st of August 1944. The post continues unfilled.

There has also been some difficulty in securing suitable clerical establishment for the Indian Roads Congress office because of the high salaries offered to clerks by the Army, and there have been some resignations. Better scales of pay may have to be offered in future.

3. OFFICE

The Office remained located at Simla and is likely to stay there as long as the Office of the Consulting Engineer (Roads) is at Simla.

During the year, the Office disposed of 1,678 receipts and issued 4,498 letters, besides doing cash and account work, and proof reading in connection with the printing of papers and proceedings. It will be observed that the work in the Indian Roads Congress Office, even as judged from the receipts and issues, has considerably increased. The staff has worked satisfactorily. The Office remained understaffed for the major portion of the year.

The Council had, at its March meeting, authorized the Executive Committee to pay for such staff as the Secretary might need. With the kind permission of the Consulting Engineer (Roads), help was taken from the Secretariat staff in the disposal of Indian Roads Congress work and, with the permission of the Government, an honorarium of Rs. 150/- each was paid to two members of this staff.

4. MEMBERSHIP

The strength of the Indian Roads Congress rose from 596 as on 1-10-43 (585 Ordinary and 11 Associate members), to 612 as on 1-10-44 (596 Ordinary and 16 Associate members). In the

year under report there were 39 admissions and 23 withdrawals due to deaths, resignations, etc. It is gratifying to note that, because of the revival of the activities of the Congress and the useful contribution that it is making towards post-war road development, more engineers are seeking admission to the Society in the current year.

The number of admissions from 1-10-44 to 26-1-45 is 43.

The Chief Engineers Conference at Nagpur had asked the Society to fix standards and specifications for roads and bridges, ruling dimensions, standard widths, super-elevations, etc., and these duties were accepted by the Council at its March meeting. The Society is now, more fully than before, acting as a clearing house of all information on highway engineering. One of its Sub-committees is revising the Code of Practice and Standard Specifications for Bridges and other Sub-committees are dealing with soil-stabilization, water bound macadam, bullock-cart design, training of the road engineers and other problems. All members of the Congress are requested to assist in the enrolment of more members from amongst qualified engineers. The Council takes this opportunity of placing on record the valuable support in this connexion received from Messrs. Murrell, and Adke, and Rai Saheb S. K. Ghose.

It may be of interest to members to hear that Professors P.C. Mahalanobis and K.B. Madhava of the Statistical Institute, Calcutta, have been enrolled as Ordinary members of the Society in the current year. An economic and traffic survey in selected localities in Bihar and Bengal is being conducted by these scientists and the Government of India have sanctioned a preliminary grant of Rs. 85,000/- for the scheme. Professor Madhava has agreed to give us a talk on the "Place of Statistics in Road Engineering", during this session. It is hoped that this contribution to the economic and statistical side of road engineering will be of much benefit to the Society and to road development in India.

5. LIFE MEMBERSHIP

At the Gwalior session in October 1943, the Council amended the rules to provide for compounding the annual subscription of members on attaining the age of 50 by a single lump sum payment for life membership. Advantage of this concession was taken by six members during the year under review. At the Lucknow meeting in September 1944, the compounding rules were suitably amended in conformity with the enhanced rate of subscription and made applicable to all members. As many as 21 members have applied for life membership under the amended rules. It is proposed to consider in the present session a proposal

to conserve the greater portion of the compounding fees for future use of the Society.

6. DEATHS

It is with deep regret that the Council has to report the death of the following members:—

1.	Rai Bahadur Sri Narayan	..	U.P.
2.	Mr. P. Balakrishnayya	..	Madras
3.	K. S. Fazal-ul-Haq	..	Bengal
4.	Mr. R. Sridhar Rao	..	Madras
5.	Mr. M. K. Narasimhayya	..	Mysore
6.	Mr. D. Nilsson	..	Gammons/Bombay

7. FINANCE

The budget estimates for the year 1944-45 and the revised budget for 1943-44 were approved by the Council at its Lucknow session in September 1944. The revised Budget closes with a deficit of Rs. 4,430 and the budget for 1944-45 would involve a deficit of Rs. 20,400, even after taking credit for the increased Government subsidy of Rs. 6,000/- if the expansion contemplated at the Gwalior session were given effect to.

The Government of India have warned the Society to conserve its resources, make all possible economics, and have a balanced budget. The full staff contemplated for efficient functioning of the Society has not been appointed and all possible economies are being effected; even so, it is very doubtful whether the Society will be able to balance its budget with its present inelastic resources. The Council feel that during the present important period in the history of road development in India it would not be right for the Society to curtail its activities. It was decided that the whole matter should be examined by a Finance Committee.

8. SALE OF PUBLICATIONS

The sale of the 7th Proceedings has so far been very poor. There is scope for further increasing sales and the Council appeals to the members to take an increasing interest in this matter and impress upon all officers engaged on road construction and maintenance, the usefulness of the Indian Roads Congress Proceedings. Members of the Council and others in Indian States are specially requested to take a keen interest in this matter as the demand for the Proceedings from Indian States is on the decline.

The Government of India were kind enough to give the Indian Roads Congress the publication and sale rights of the Nagpur Report. The Society had previously printed at its own cost the Agenda, Memoranda, and the Draft Report of this Conference and, after meeting all charges, including a demand from Government for over 1,000 free copies, expects to make a small profit on this publication which will go towards reducing the deficit for the current year.

As soon as normal conditions recur and the cost of paper and printing becomes more reasonable, the Council hopes to print several books and papers for which it expects there will be a ready sale.

The attention of members is called to the new form in which the papers and proceedings are being published. It is hoped the new system, which is discussed in Enclosure I*, will meet with general approval. Suggestions for further improvement are invited.

9. INTELLIGENCE

Enquiries were received from members and others on various subjects, including the interpretation of the Standard Bridge Specifications and the Code of Practice. Information available was supplied or reference to relevant literature was furnished.

10. LIBRARY

During the period under report, the libraries of the Consulting Engineer (Roads) and the Indian Roads Congress have been considerably enlarged. An expenditure of Rs. 351/- has been incurred from Indian Roads Congress funds alone for purchase of books. A supplementary list of books that have been added to the two libraries since the issue of the previous catalogue in May 1943 is under print and will be distributed to members in due course. A list of new additions has not therefore been made in the Report.

Very many modern books on road engineering, soil mechanics, economics of Road engineering, research in various branches of highway engineering, etc., have been purchased. It is regretted that the libraries are not being used to the fullest extent. They are available for [illegible] all the members and the Indian Roads Congress bears the [illegible] of transit one way. All members are requested to make an increasing use of the libraries. Suggestions from members regarding books to be purchased and for increasing the efficiency of the library will be welcomed.

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*Printed on page 23.

TECHNICAL ACTIVITIES OF THE CONGRESS

11. *TECHNICAL SUB-COMMITTEE*—After the last report to the Council in October 1943, the Technical Sub-committee met at Alipore on the 10th and 11th November 1943 and decided:—

(i) To carry out tests on the comparative performance of graded and ungraded stone in "cretes" with cut-backs, hot mix bitumen, or tar;

(ii) to carry out comparative tests on steel tyred cart wheels as well as broad wooden tyred wheels and to compare their relative performance when tested under Test Track conditions, the tests to be undertaken to fill in the time required for preparing for the tests under item (i).

Test indicated in item (ii) above were not carried out as wheels were not ready in time.

The specifications for "cretes" were discussed by the Sub-committee at Bombay in March 1944, and finalized and a Local Committee, consisting of Messrs. Chambers, Fielder and Chowdhari, was constituted to take quick decisions on any doubtful points.

Because of transport difficulties much time was spent in collecting materials, but the "cretes" have now been laid and tests are to be started soon. A detailed report of the work done in the year will be made by the Sub-committee to the Council.

Our thanks are due to Messrs. Sen Gupta and Chowdhari for the keen interest they have taken in the road Test Track work.

12. *SOIL RESEARCH*

The Soil Sub-committee was in abeyance for three years but met at Lahore in January 1944, reviewed the results of some experimental field tests on roads in the Punjab, and recommended to the Government of India a programme for experimental field tests on a very large scale. As a first step, it was suggested that experimental work on soil stabilization over 25 miles of road in the Punjab should be taken on hand. This recommendation was accepted by the Government of India, and it agreed to give a grant of Rs. 1 lakh for the work, provided the Punjab Government also subscribed Rs. 1 lakh. The Punjab Government accepted the conditions laid down by the Government of India and formed a special Division for the work.

The road selected for the experimental work is the Batala Sri-Govindpur road and soil-stabilization has so far been completed in 4 miles. It is expected that the whole work will be completed before March 1945. A soil research laboratory has also been opened at Lahore with a small staff.

13. *EDUCATION SUB-COMMITTEE*

This Sub-committee was appointed by the Council at its meeting at Bombay. Mr. V. N. Rangaswamy, who is the present convener, has prepared a comprehensive scheme for revision of syllabuses in engineering colleges, institution of a Chair on Highway engineering, deputation of road engineers to foreign countries for study, and providing Refresher Course at several centres. Mr. Dean, who has just returned from England, has also collected much valuable information. The Committee will meet at this session and discuss proposals put forward by its members.

14. *BRIDGES SUB-COMMITTEE*

Since the last report in October 1943, considerable work has been done in revising the specifications and Code of Practice for Road Bridges. The Sub-committee met in the year under review 4 times: at Bombay in March, at Calcutta in May, at Simla in August, and at Lucknow in September 1944. The main items considered were:—

(i) Bridge Loadings

(ii) Impact, and

(iii) Ruling dimensions.

Agreed conclusions have been arrived at. Some chapters of the Code have also been written. Due to the preoccupation of both the Convener and the Secretary, with other business, it has not been possible to make more rapid progress. It is, however, hoped that the draft specifications will be ready before the next General Session. Copies will be circulated to members for comments before the Code is finalized.

Mr. H. K. Nivas and Rai Bahadur Brij Narain have been recently co-opted as members of this Sub-committee.

15. *SIR KENNETH MITCHELL FUND*

A total of Rs. 3,758/- was contributed by members for this fund. Mr. Dean, when on short leave in England in July last, was kind enough to get a design for the medal, and a die cast in the Royal Mint, London, at a cost of Rs. 2,696/-. The Medal has since been received and can be seen by members. There is a balance of only Rs. 1,062/- in the fund which is hardly sufficient to achieve the objects for which the fund had been instituted.

The Council appeals to all the members who have not so far contributed to this fund to send in their contributions as early as

possible, and to more senior members to make a further donation. About Rs. 1,500/- more is required.

16. *WATER-BOUND MACADAM*

At the Bombay session of the Council in March 1944, the Council appointed a Sub-committee to draw up authoritative specifications for water-bound macadam surfaces. The convener, R. B. Lakshminarayana Rao, circulated to the members a few of the specifications in vogue in Madras. A comprehensive report on the subject has since been prepared and it was intended to publish this as a Paper but for want of time and pending further examination by members of the Sub-committee, it has not been possible to include it for discussion in the ensuing session. It is hoped to publish this at an early date in the Journals of the Society.

17. *ROAD RESEARCH*

At the Lucknow session of the Council, a Special Sub-committee consisting of Mr. Vesugar, Sir Kenneth Mitchell, Brigadier Obbard, and Messrs. McKelvie, Dean, Shannon, Fielder, Chowdhari, Kynnersley and Raghavachary, was appointed to examine urgently a scheme for the setting up of a Road Research Institute. This scheme was to be submitted to the Government of India and to a Committee of the Council of Scientific and Industrial Research who were considering schemes for *scientific research* in various branches. The Sub-committee met on 17th October at Delhi and drew up a detailed scheme and organization chart. These are now under the consideration of the Government. A copy is laid on the table and copies have been sent to all Chief Engineers of Provinces. The final report will be printed in the Journals of the Society.

18. *BULLOCK-CART SUB-COMMITTEE*

This Sub-committee was constituted at the Gwalior session in October 1943. It has since met thrice. At the Bombay meeting, the Committee examined a new design by Mr. Burges and a sample of his wheel, but considered that several improvements were necessary before it could be accepted.

Mr. Vagh, an active member of this Committee, is reading a paper on the design of the bullock-cart wheel. Various alternative designs have been discussed in the paper and it is hoped that there will be a lively discussion on the subject.

Rao Bahadur Nageswara Ayyar had also evolved two alternative designs for bullock-cart wheels. The Govt. of India have

sanctioned Rs. 300/- to meet the cost of one set of experimental wheels.

The Congress will endeavour, after considering various proposals discussed in Mr. Vagh's paper and Rao Bahadur Nageswara Ayyar's note, to evolve designs for trial in various provinces.

19. *DEMOBILIZATION SUB-COMMITTEE*

At the Lucknow session of the Council in September 1944, it was considered that the question of absorbing demobilized personnel from the Army in post-war road development work should be examined by a small Sub-committee, consisting of Mr. Vesugar, Sir Kenneth Mitchell, Brigadier Obbard and Messrs. McKelvie and Raghavachary. The Committee met on the 18th October 1944 at Delhi for a preliminary discussion. Brigadier J.H. Wilkinson of the Resettlement Directorate attended by invitation. The Sub-committee made certain recommendations which will be forwarded to Government. A copy of these recommendations is laid on the table and the final report will be printed in due course. It is proposed further to consider this question at Madras on the 10th February 1945.

20. *VICEROY'S WAR PURPOSES FUND*

The total contribution made by the members to this fund amounted to Rs. 1,466/14/- and the Congress contributed Rs. 33/2/- to make up a round figure of Rs. 1,500/-. This amount has been sent by cheque to the Treasurer of H.E. the Viceroy's War Purposes Fund, and the account has been closed.

21. *PRIZE ESSAYS*

At the Gwalior session in October 1943, Sir Kenneth Mitchell and Mr. Nur Mohammad Chinoy jointly offered a prize of Rs. 250/- for the best essay on "Post-war goods and passenger road transport and its economics". As only one essay has been received and it is not of the standard expected, the Council proposes, with the concurrence of the donors, to keep the competition open for another year. The Council further decided that a Committee should fix the subject for the medal competition and deal with essays received for both the medal and prize essay competition.

In 1941, the Congress offered a prize of Rs. 100/- for the best essay on Technical Education of the Road Engineer. An essay by Mr. V. N. Rangaswamy was adjudged to be the best. The medal for this prize essay has not been awarded so far due to difficulty in getting a suitable die cut but this has now been done in the Royal

Mint, London, with the kind help of Mr. Dean. It is hoped to present this medal to Mr. Rangaswamy at this session.

Finally, the Council takes this opportunity of thanking all the members of the Society for the co-operation and help they gave the Secretary on all occasions. Special thanks of the Council are due to Mr. Vesugar and Mr. McKelvie who have at all times given the Secretary necessary guidance and help. The Society has been very active (much more so than at any time in its history) since its last session at Gwalior in October 1943. Two Council meetings, two Sub-committee meetings and three meetings of the Executive Committee have been held since then at different places and times. Every effort was made by our hosts at different places for the convenience of members attending these meetings, and the Council is grateful to the local organisers for what they did at considerable personal inconvenience to themselves.

22. The proceedings of the Council meetings held at Bombay and Lucknow, during the year under review, will be printed in the Journal for the information of members. Attention is called to the following important points which were discussed at these meetings :—

(i) The Council both at its Bombay and Lucknow meetings reiterated the recommendation made by it at the last general session that a "Road Board" should be constituted at an early date ;

(ii) The recommendation of the Council at its Lucknow meeting that a Roads Transport Congress on parallel lines to the existing Indian Roads Congress should be formed, was forwarded to the Government of India; and

(iii) The following recommendation of the Council at its Lucknow meeting was also brought to the notice of Government of India :—

"The Council recommends that the Government of India be requested to suggest to Provinces that they should provincialize the Engineering Staff of the District Boards at once and bring them on to a common cadre."

REPORT OF THE COUNCIL FOR 1943-44

Copy of Circular No. 9. I. R. C., dated 14th November 1944. †

Papers for the next General Session.

As members are aware, it has been the practice in the past to send advance copies of "papers" to members for prior study before discussion at the General Session and to send again another copy with discussions, etc., in a bound volume.

2. Because of the shortage of paper, it has been decided to suspend the issue of duplicate copies along with the proceedings. The accepted papers will be issued in a complete form in sets of two or more. Members are requested to preserve their copies and bring them to the Session. The comments of members and discussions on the papers at the General Session will be incorporated in a separate volume.

3. The format of the publications of the Society has been changed and made the same as that of the Institution of Civil Engineers, London. The method of printing the papers described above is the same as that adopted by the Institute. It is hoped members will find the reduced size convenient as the books can easily be carried in a coat pocket.

4. As soon as stocks are available at reasonable price it is proposed to issue Spring covers to members so that the relevant papers and discussions thereon can be kept together under one cover.

ED 30th SEPTEMBER 1943.

		Sales.	Closing Stock.	Total.
		Rs. a. p.	Rs. a. p.	Rs. a. p.
Inaugu	..	18 8 0	0 12 0	19 4 0
Second	..	25 8 0	27 4 0	52 12 0
Third	..	25 8 0	51 8 0	77 0 0
Fourth	.	28 8 0	46 12 0	75 4 0
Fifth	..	75 0 0	3 12 0	78 12 0
Sixth	..	..	0 4 0	0 4 0
Sevent	..	48 10 0	74 12 0	123 6 0
Bridge	..	148 12 0	157 0 0	305 12 0
Total	..	270 6 0	362 0 0	732 6 0

D 30th SEPTEMBER 1943.

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.. .. ..	..	744 6 0
d Recovered	..	308 0 0
FICIT for the year carried to	..	311 10 3
Total ..	..	11,447 0 3

Annexure to our report of date,

AIYAR & CO.,

REGISTERED ACCOUNTANTS,

Auditors.

Annexure I

LIST OF MEMBERS WHO ATTENDED THE IXth SESSION OF THE INDIAN ROADS CONGRESS HELD AT MADRAS IN FEBRUARY, 1945.

Government of India

1. J. Vesugar.
2. G. M. McKelvie.
3. K. S. Raghavachary.
4. Sham Lal Bazaz.
5. Prof. K. B. Madhava.

C. P. W. D.

1. A. W. H. Dean.
2. B. S. Puri.
3. A. N. Chopra.
4. V. S. Annaswami.
5. S. Guruswamy.
6. H. P. Sinha.

E-IN-C's BRANCH

1. H. N. Obbard.

Other members at Delhi

1. Jivan Datt.

Madras

1. A. Lakshminarayana Rao.
2. C. L. Berg.
3. T. Lokanatha Mudaliyar.
4. S. H. Dhanarajan.
5. N. Durrani.
6. N. T. Gnanaprakasam.
7. G. Gopalacharya.
8. P. A. Krishnaswamy.
9. K. S. Krishnan.
10. O. C. K. Krishnan.
11. Ch. Madhavarao.
12. A. Nageswara Ayyar.
13. K. K. Nambiar.
14. B. N. Shenoy.
15. H. C. Padhi.
16. K. Ramamurti.
17. V. H. Sadarangani.
18. V. N. Rangaswami.
19. B. Satyanarayana.
20. H. R. Sayoji Rao.
21. T. Sekharan.
22. P. Sirajudin.
23. K. Srinivasan.
24. M. S. Srouty.
25. P. Venkataramanaraju.
26. V. S. Rangaswami.
27. A. S. Anantanarayana Ayyar.
28. G. Sri Rangachariar.
29. T. Kedaram.
30. R. Krishnaswamy.
31. S. C. Nayak.
32. C. J. Rao.
33. M. Meeran.
34. T. V. Rangaswami.
35. K. V. Thadaney.
36. N. Sheshageri Rao.
37. Mohd Shearli Sahib.
38. M. W. Gnanamani.
39. K. Subba Rao. (Mckenzies)
40. K. Subba Rao. (Bellary).
41. P. T. Narayana Nayar.
42. S. Narayanswami.
43. H. Sundara Rao.
44. T. S. K. Mudaliar
45. S. R. Naidu.
46. K. Ramaswamy.
47. P. V. Raj.
48. P. G. Mathew.
49. P. Narayana.
50. K. S. Subramanyam.
51. K. Trimulaswami Ayyar.
52. J. G. Abraham.
53. U. Ananda Rao.
54. P. S. Patrulu.
55. J. O. Parkhill.
56. K. A. N. Chetty.

Bombay

1. C. G. Kale.
2. N. P. Gurjar.
3. A. S. Adke.
4. T. R. S. Kynnersley.
5. N. V. Modak.
6. B. V. Vagh.
7. Ian A. T. Shannon.
8. W. J. Turnbull.

(ii) Ordinary and Associate Members who leave India on retirement are allowed to compound their annual subscription for a sum of Rs. 25/- for so long as they reside outside India, Burma and Ceylon.

(iii) Ordinary Members whose subscriptions are not in the arrears may compound their future annual subscriptions by a single payment depending upon their age at the time in accordance with the age table below.

Associete Members of 55 years and over may, on the retirement from their profession, become ordinary members and compound for life by a single payment, according to same table.

Age Table for Compounding for Life Membership

Age*	Compounding fee	Age*	Compounding fee	Age*	Compounding fee
25	298	36	230	47	135
26	293	37	222	48	125
27	287	38	215	49	115
28	282	39	207	50	104
29	276	40	198	51	93
30	270	41	190	52	82
31	264	42	182	53	70
32	257	43	173	54	58
33	251	44	164	55	45
34	244	45	155	56	30
35	237	46	145	and over.	

*Age shall be reckoned as that on the birthday nearest first October of the year of commuting annual subscriptions.

(iv) A year shall, for the purposes of this Rule, be from the first day of October until the last day of September following. Subscription shall be due on election and on the first day of October of every year following that date while a person continues to be a member of the Society. Provided that if a person is elected as a member of the Society after the 31st March in any year, he shall only pay half subscription for that year.

(v) The fee paid for commutation for life membership shall after deduction of Rs. 10/- for initial expenses be transferred to a separate life membership reserve, and invested as in 2 (g) of the Memorandum of Association, to be used for such purposes as the Council may from time to time decide.

(b) Certain amendments to the Rules and Regulations moved by Rao Bahadur Lakshminarayana Rao were informally discussed. The mover was permitted to withdraw his proposal.

4. The Council expressed its thanks to Messrs. Dean, Medd, Craig and Shaw for their assistance in the matter of preparing a design and cutting dies for the Indian Roads Congress and Mitchell medals.

5. The Council noted that the reading of the proposed paper on "Road and Road Transport Problems" had to be deferred.

6. Reports on the work of the various Sub-committees were taken as read and confirmed.

7. The proposal that the Proceedings and papers of the Congress should be issued periodically in the form of Journals was approved with the proviso that copies of the complete proceedings and papers for each year, bound in one volume, be made available for purchase by members.

8. After disposing of other minor items in the Agenda, the meeting concluded.

Annexure III

Minutes of the 23rd COUNCIL MEETING of the Indian Roads Congress held at Madras on 10th and 11th February, 1945.

Present :—

President :— J. Vesugar.

1. A.W.H. Dean,
2. G.M. McKelvie,
3. C.L. Berg,
4. C.G. Kale,
5. A.H. Nunn,
6. S.N. Chakravarti,
7. L.A. Freak,
8. B. St. J. Newton,
9. F.E. Cormack.
10. W. Lawley.
11. W.B. Calder,
12. Brig. H.N Obbard,
13. G.M. Khann,
14. M.V. Krishnaswamy,
15. Major N.K. Bhonsle,
16. D.N. Gupta,
17. I.C. Chacko,
18. U.J. Bhat,
19. H.E. Ormerod,
20. Ian A.T. Shannon,
21. T.R S. Kynnersley,
22. C.J. Fielder,
23. Nur Mohd. Chinoy,
24. W.B Bakewell,
25. T. Lokanathan,
26. Rai Bahadur C.P. Misra,
27. K K. Nambiar,
28. N.V. Modak,
29. V.N. Rangaswamy,
30. Rai Sahib Fateh Chand.

Secretary :— K.S. Raghavachary.

1. The Minutes of the 22nd Council meeting, (pages 29-31) held at Madras on 6-2-45, were confirmed.

2. The following office-bearers were elected to hold office till the next General Session.

President :—	J. Vesugar.
Vice-Presidents	A.W.H. Dean, H.E. Ormerod, N.V. Modak.
Hon. Treasurer .—	G.M. McKelvie.
Hon. Secretary :—	K.S. Raghavachary.

3. The Council then proceeded to elect sub-committees for the work of the Congress. Details are set out in *Enclosure I* (pages 36-37).

4. A note on Local Board Road Administration and suggestions for its improvement (Enclosure II—page 38), prepared by Mr. K.S. Raghavachary, had been circulated to the members. One of the newly formed sub-committees was asked to examine this note and suggest a scheme for the consideration of Provincial Governments on the provincialisation of the District Board Engineering staff and the best method of improving the administration of District and Village Roads, while, at the same time, associating local opinion with their development.

5. The proposal to form a "Road Transport Congress" on the lines indicated at the Lucknow Council Meeting was discussed. It was agreed that a small Sub-committee consisting of Mr. Nur Mohd. Chinoy; Mr. H.E. Ormerod, and Mr. T.R.S. Kynnersley should work details of the scheme so that concrete proposals might be put bofore the Government of India.

6. The Council decided to meet at Delhi sometime in July 1945, if possible, to review the progress made by the several Sub-committees and to implement the scheme for post-war road development.

After discussing proposals to hold the next General Session at Udaipur, Jaipur, Kalimpong, and Karachi, the Council decided to settle the matter at its meeting in July 1945.

7. The Council decided that two medals should be available for competition every year, in future, the Mitchell Medal and the Indian Roads Congress Medal. In addition, it was decided that the competition for the best essay on "Post-war Goods and Passenger Road Transport and its Economics" to be presented jointly by Sir Kenneth Mitchell and Mr. Nur Mohd. Chinoy, should be kept open for another year. Mr. Nur Mohd. Chinoy agreed to this on behalf of the donors.

The Executive Committee was authorised to frame rules for the competitions and in framing these rules, to provide that the Council should be in a position to withhold the award, or award more than one medal of each class during any year.

It was also decided that the Indian Roads Congress Medal should be reserved for exceptionally good papers contributed by members in any year. Council members would not be eligible for the award of prizes or the Mitchell Medal but might receive honourable mention.

The following were suggested as suitable subjects for the next Mitchell Medal competition:—

(i) Road-mindedness—How to create a widespread public demand for more and better roads in India.

(ii) Cheap Rural Roads and their Economics.

(iii) Economics of Road Maintenance.

(iv) Cycle Tracks and Pedestrian Pavements.

As much publicity as possible is to be given to the competition for the prizes and medals.

8. The matter of requesting the Government of India for an increased subsidy was left to the Finance Sub-committee to decide. A suggestion was made that the Provincial Governments might

be approached to contribute towards the general expenses of the Indian Roads Congress on the lines of the contributions paid by certain Governments to the Central Board of Irrigation. Mr. McKelvie remarked that a body very similar to the Indian Roads Congress exists in the U.S.A. It is called the American Association of State Highway Official and it is financed entirely by the State Governments.

The Secretary was instructed to address Chief Engineers of Provinces demi-officially to ascertain the reactions of Provincial Governments on the subjects. There was a general feeling on the part of representatives of these Governments on the Council that each Province would be prepared to contribute Rs. 2,000/- or so.

The Finance Sub-committee will work out a detailed scheme after examining the needs of the expanded office.

9. DEMOBILISATION.

Brigadier Obbard explained that he had in mind a proposal to form construction co-operatives on the lines of those which have functioned most successfully in America, in Australia, and in Italy. He was of the opinion that these co-operatives were able to work and produce results more cheaply than could contractors. In Italy these Societies consisted almost entirely of unskilled men, and when necessary they engaged skilled labour who became temporary members of the Society for the period for which they were employed.

In the same way, machinery required for particular jobs was hired by the Societies. He asked whether it would be possible for Provincial Governments to hire machinery to the proposed societies.

After discussing the employment of demobilised men, on road transport, Brigadier Obbard asked the Chief Engineers present to collect figures showing the extent to which returned soldiers could be employed on the projects. He also asked what the Congress considered would be the extra cost of employing demobilised men on post-war road construction.

The general opinion was that so long as demobilised personnel were willing to work on piecework system and paid by results, there would be no difficulty in employing such men. If, however, returned soldiers prove to be more expensive than ordinary workmen, the extra cost should not be charged to the road projects.

10. REPRESENTATION ON THE POLICY COMMITTEE

The Council discussed the suggestion contained in item 6 of the Business meeting (page 12) and instructed the Secretary to

request the Government of India to give representation to the Congress through the President or his nominee on the Policy Committee No. 3-A on Transport.

11. Other suggestions made at the business meeting were then considered. It was decided that the suggestions received for facilitating business at general sessions should be discussed at the next Council meeting, when rules of procedure and allocation of work among members, will be decided; that a wholetime organising Secretary for the General Sessions should be engaged in future, the hosts being requested to nominate this officer; and that the Council members should be addressed by a special circular to consider items of work dealt with in the past few years, and make them suggestions. Further consideration to these matters will be given at the July meeting of the Council.

12. It was agreed, at the instance of the President, that in future a convention should be established whereby the President would discuss his proposed presidential address with the Executive Committee and accept the majority opinion before delivery. A few members however held the view that the discretion of the President should be unfettered, but the President explained that as his address carried weight only in so far as it expressed the general collective opinion of the Society, he would himself welcome the advice of the Executive Committee in the matter.

The Council Meeting then concluded.

Enclosure I to Annexure III

SUB-COMMITTEES APPOINTED BY THE COUNCIL

1. Technical Sub-committee.

It was decided that the Technical Sub-committee should be split up into divisions as follows :—

(a) Test Track Division.

Mr. J. Chambers (Convenor)

Dr. A.N. Chowdary	Mr. G.M. McKelvie
Mr. C.J. Fielder	

(b) Road Transport Division.

Mr. H.E. Ormerod (Convenor)

Mr. A.W.H. Dean	Mr. T.R.S. Kynnersley
Mr. N.M. Chenoy	

(c) Specifications and Standards Division.

Mr. K.S. Raghavachary (Convenor)

R.B. Brij Narain	Mr. C.G. Kale
Mr. W.B. Calder	Mr. W. Lawley
Mr. S. N. Chakravarti	Mr. L.A. Freak
Mr. C.L. Berg	Mr. K.K. Nambiar
Mr. Dildar Hussain	A nominee from Assam

(d) Research Organization Division.

Mr. A.W.H. Dean (Convenor)

Sir Kenneth Mitchell	Brig. H.N. Obbard
Mr. I.A.T. Shannon	Mr. T.R. Kynnersley
Mr. C.J. Fielder	Dr. A.N. Chowdary

2. Bullock Cart Sub-committee.

Mr. B. V. Vagh (Convenor)

Mr. Dildar Hussain	R.B. A. Nageswara Ayyar

3. Soil Research Sub-committee.

Mr. A.W.H. Dean (Convenor)

Mr. L.A. Freak	Mr. U. J. Bhatt
Dr. V.I. Vaidyanathan	Mr. S.R. Mehra
Mr. I.A.T. Shannon	Nominee of E-in-C's Branch.

4. Education Sub-committee.

Mr. V.N. Rangaswamy (Convenor)

Mr. N.V. Modak	Mr. T.R S. Kynnersley
Mr. A.W.H. Dean	Prof. K.B. Madhava (co-opted)

5. Bridges Sub-committee.

Mr. G.M. McKelvie (Convenor)

Mr. J. Chambers	Mr. E.P. Nicoloides
Mr. W. Lawley	R.B. Brij Narain

6. Water Bound Macadam.

Mr. K.S. Raghavachary (Convenor)

R.B. A. Lakshminarayana Rao
Rai Sahib Fateh Chand
Mr. C.J. Fielder
Mr. T. Lokanathan
Mr. A.S. Adke
Mr. F.E. Cormack (co-opted)

7. Demobilization Sub-committee.

Mr. J. Vesugar (Convenor)

Sir Kenneth Mitchell
Brig. H. J. Wilkinson
Brigadier H.N. Obbard
Mr. A.W.H. Dean

8. Executive & Finance Committee.

President, Vice-Presidents, Hon. Treasurer, and Hon. Secretary.

9. Bituminous Treatment of Wet Aggregates.

Mr. C. J. Fielder (Convenor)

Mr. I.A.T. Shannon
Mr. A.W.H. Dean
Mr. J. Chambers
Mr. W.B. Bakewell
Mr. H.A. Harris
Dr. A.N. Chowdary

10. Highway Layout Sub-committee.

Mr. H.E. Ormerod (Convenor)

Mr. T.R.S. Kynnersley
Mr. G.M. McKelvie
Mr. A.W.H. Dean

Enclosure II to Annexure III

A note on the Road Administration
by the
Local Bodies, and suggestions for improvement.

By Mr. K. S. Ragharachary

I. Historical.

(i) Certain roads have been in charge of Local Bodies in Madras since 1871 and it is assumed that local bodies in other provinces have been in charge of roads for a similarly long period. Until two or three decades ago, however, these bodies were largely under official control.

(ii) In 1917, the P.W.D. Reorganisation Committee (the Sly Committee) recommended that local units like District Boards, helped by a State subsidy, and *subject to State control*, should take over greater responsibility for roads.

(iii) It is now generally admitted that, as the District Boards became more and more autonomous with elected Presidents not subject to Government control, the efficiency of road administration gradually got worse. The development of "roads" was not properly planned under a general policy, but was often sporadic to suit the wishes of individual members of the Board whom the President had to humour if he wished to stay in office; maintenance was neglected; and frequently funds earmarked for roads, such as the Road cess and the Revenue accruing from the users of roads, were diverted to other services. There was also insufficient superior technical control; the District Board Engineer had no voice in fixing the minimum amounts allotted for the roads to keep them in proper repair, and had very little control over his staff. His continuance in office often depended on his being able to accommodate himself to the views of the President of the Board who was changed every 3 years. Corruption crept in; party interests played a large part, not only in determining policy but in the day-to-day management of road work; and general efficiency of the administration deteriorated gradually, and finally reached such a low mark that, in Madras, the abolition of the District Boards altogether was seriously considered at one time.

II. Present Position.

2. (i) The conditions described in paragraph 1 above relate particularly to Madras as information concerning this province is recorded in our office but it is generally known that they were even less satisfactory in some other provinces and nowhere any better. The question of improving matters has often been considered and in recent years the Transport Advisory Council set up by the Government of India have also paid attention to the subject.

(ii) The Transport Advisory Council consists of representatives of Provincial Governments and administrations. It recorded a note on the relations of Provincial Governments with Local Bodies in regard to the control of Road systems, in which it was mentioned that "the condition of metalled roads in charge of local bodies is generally poor and that these roads are generally inadequate for the traffic ... ...The main obstacles to progress appear to be administrative and technical, and financial.. .. There appear to be two alternatives, viz.

(a) the restriction of the sphere of local bodies to the construction and maintenance of such roads as they can adequately finance from their own resources and the transfer of the remainder to the Provincial organisations, or

(b) the utilisation of local bodies for the construction and maintenance of roads to such an extent, as may be considered desirable.

"In either case, supervision and control would be required and in the second case, Provincial Governments should have power to insist upon adequate maintenance of roads constructed out of the Provincial grants........it may be necessary to overhaul the machinery of control (possibly by enacting legislation) so as to empower the Provincial authorities to ensure that Provincial funds are not wasted".

(iii) The following conclusions were adopted by the Council after discussion :—

"(a) The standard of District-Board Roads is below the needs, and except in Madras, present arrangements lead to a lack of balance in the road system.

(b) Control by Provincial Governments in the matter of road development and maintenance is, in most of the Provinces, inadequate to present-day requirements. There should be effective control by Provincial Governments, which should extend to—

(i) the fixing of the proportion of Local Fund revenue that should be applied to roads ;

(ii) ensuring adequate maintenance ; and

(iii) providing that the District Board Engineering staff are properly qualified, have security of tenure and adequate remuneration.

(c) Funds derived from the Central Road Fund or Provincial revenues should not be granted to local bodies without full control over the execution of the work and reasonable certainty regarding future maintenance."

(iv) The first and third conclusions were ratified by all Provincial Governments and the Provincial Governments reported that action was being taken to implement the recommendations contained in the second resolution.

3. The deplorable position of roads in the District Boards has been very well brought out by Sir Kenneth Mitchell in his Presidential address to the 8th Session of the Indian Roads Congress held at Gwalior in October 1943. (Paras 18 to 22 of the speech*). Salient features are extracted below.

* * *

"Now, the present general condition of this extensive system of roads, ... seems to me to be a reproach to our generation, and also a barrier to every other plan of rural uplift or improvement........But what is, I fear, a common cause of the present state of affairs, is an administrative misfit... ..

"As I see them, two simple facts are inescapable. On the one hand, local self-government has had a long and fair trial; on the other, the roads are no better......even the money budgeted for roads could often have been better or more wisely spent........the financing of post-war development and the overtaking of years of neglect will be quite beyond the existing and potential resources of local bodies, and probably also the maintenance of the resulting improved system.

"It seems to me to be a sound axiom of public finance that the Government, Legislature, or Local Body that imposes the taxation should be directly responsible for the use of the money and answerable for its abuse or waste........the status and conditions of service of District Board Engineers are often not such as to make for efficiency. Deprived, as they frequently are, of any support and guidance from official professional superiors, they are always in danger of stagnating and dare not experiment or try to get out of the grooves bounded by conservatism and

*Presidential Address—Vol. VIII—I.R.C. Proceedings.

the vested interests of contractors....... the average District Board Engineer has no time to keep himself up-to-date and to isolate him and his problems in each District must mean obstruction of progress.

"....the size of the world is shrinking........The Province has in fact become a suitable area for road management, and the isolation of district management is no longer necessary nor is it desirable.

"Therefore .....the first step towards the improvement of District roads is to transfer them to expert Provincial Highway Departments, which would absorb the efficient District Board Engineers and level up standards of efficiency all round......Reforms must be radical........ let our engineers be organised into regular Highway Departments and get into two groups with these problems."

4. The Chief Engineers of Provinces and States who met at Nagpur in December 1943 to make recommendations to the Government of India on post-war road development stated that "nearly everywhere local bodies have failed both in the matter of construction and maintenance of work owing, sometimes to political interference, sometimes to the fact that the staff recruited for small areas and to administer petty budgets were poor in qualifications and lacking prospects, and generally because of the well-established principle that small units with limited resources and outlook are not in a position to give direction, except in petty matters." Various proposals were suggested.—(Paras. 87 & 88 of the Nagpur Report).

5. The Government of India in the Posts and Air Department in their Ref. No. R184 dated 29.2.1944 addressed in the following terms the Provincial Governments for their views on the recommendation of the Chief Engineers that no post-war road development work should be carried out through the agency of Local or District Boards.

13. **Administration.** There are two subjects touched on under this head, namely, the proposed Road Board and the expansion of the office of the Consulting Engineer to the Government of India (Roads), (dealt with under para. 6 of this letter), and appointment of special establishments in the Provinces and States to undertake planning work.

As regards the second subject, the following are the most important recommendations:—

* * *

(ii) that no post-war road development work in the programme outlined by the Chief Engineers should be carried out through the agency of Local or District Board, and

(iii) that the questions of reducing the size of Public Works Department executive charges, delegating more powers to executive engineers and absorbing competent staff of local bodies in the P.W.D. cadre should be examined.

These three recommendations relate to matters which are wholly in the Provincial Field and the Government of India recommend them for careful consideration and acceptance of the Provincial Government (and request that their views may be intimated to this Department)."

III. Agreement on policy by Provincial Governments.

6. (i) The Provincial Governments except Madras have accepted in principle (with minor modifications) the recommendations made in the Nagpur Report. They have conceded that roads under District Boards have deteriorated considerably in recent years due to lack of funds, inadequacy of qualified staff and undue interference by the members of the Board.

(ii) The Madras Government, who took a lead several years back in attempting to improve matters contend that they had already accepted and acted on the policy recommended. They have already introduced a rigid system of control with a Provincial Service of District and Assistant Engineers, supervised by 3 Superintending Engineers and one Chief Engineer (Communications). Thus complete centralisation of Local Board service has been attained, and the political influences and nepotism attributable to the Local Bodies in other provinces have been practically eliminated. The Government has also complete control over District Board contracts. A special officer was appointed last year further to consider taking over the more important roads from Local Bodies. His report is under consideration of the Government. A brief note on the evolution of the present advanced system in the Local Board administration is placed below. (Encl.)* Madras is contemplating setting up of a Highway Department as contemplated by the Chief Engineers. The large milage of roads in Madras is claimed to be mainly due to the control exercised by the Provincial Government over the Local Boards.

(iii) Bihar is now also taking action and has brought forward a bill to provincialise the District Board Engineering Service.

7. The Indian Roads Congress, who have been considering this subject for some years past, and making recommendations to the Government in this behalf, considered the question again at the Council meetings held at Bombay in March 1944 and at Lucknow in September 1944, and after considerable discussion on both the occasions recorded as under.

Minutes of the 20th I.R.C. Council meeting held at Bombay in March 1944.

"(i) The resolution regarding provincialization of the Service of District Board Engineers is dealt with for the main part under item 8 (v) of these Minutes. It was decided that to give effective support to the principle underlying the resolution (which the Council approves), it will be necessary before submitting a further formal resolution on the subject to the Provincial Governments, (the Governments concerned), to study the full implications of the proposal and devise

*Not enclosed.

means of giving effect to the change since the Council is not satisfied that an unmodified acceptance of the Madras precedent would be in the public interest. The Executive Committee will draw up a note on the subject and consult Members interested before the next meeting of the Council when the proposale will be further discussed.

"(ii) Resolution regarding unspent balances of road funds lying with District Boards.

(a) Several Members brought to the notice of the Council that, owing to the present condition of shortage of supplies, high prices and difficulties of transport, road maintenance was being neglected in many places, and particularly in the case of District Boards, the funds ordinarily reserved for this purpose were being diverted to other objects. The proposer of this Resolution stated that his own Provincial Government had issued an order that funds earmarked for Education should not be diverted to other purpose in cases where there was a delay in carrying out educational schemes but should be reserved and spent at a latter date on the schemes for which they were originally allotted. He suggested that Provincial Governments should be asked to issue similar orders regarding funds ordinarily allotted for communications.

"(b) It was generally agreed that due to war conditions there were serious gaps in road maintenance in many areas. The Council agrees with and amplifies the recommendation made in paragraph 72 of the Nagpur Report, viz., that the autorities responsible for communications should be prepared to accept an increased liablity for maintenance over pre-war costs in the ratio that current costs bear to pre-war costs. It was suggested that the Congress should recommend that the Government of India when distributing Road Fund and other grants from the Centre, should take into account any neglect of maintenance and diversion of funds from communications on the part of Provinces and States and that these administrations should similarly take into account similar diversions made by local bodies. This would follow the practice adopted in the U.S.A. where the Federal Aid Act provides a a penalty for excessive diversion of funds from Highways."

The following Resolution was passed :—

"The Council views with concern the serious gaps apparent in the road maintenance and programe in many areas. It realizes that owing to war conditions of short supplies, high prices, and transport shortage, it is difficult to ensure proper road maintenance but it is seriously concerned with the greatly disproportionate wastage in the road assests of the country which neglect of maintenance will entail. The Council endorses and amplifies the recommendation made by the Chief Engineers at their Nagpur Conference in December 1943 (paragraph 72) that all authorities responsible for the upkeep of roads should be prepared to spend on road maintenance not only the sum that was spent before the war but in addition a sum representing the difference between current and pre-war costs of executing repairs. The Council recommends that steps should be taken by Provincial Governments to prevent diversion to other purposes by local bodies of funds allotted for road maintenance. It also advises that when post-war reconstruction work is to be taken up. these administrations which have through default permitted serious wastage of their road communication assets, should not be allowed additional funds from any source provided by the general taxpayer or road users in general, to repair those locally wasted assets at the expense of administrations which have husbanded their local road assets".

Minutes of the 21st I.R.C. Council meeting held at Lucknow in September 1944.

* * * *

Para 36. Provincialization of District Board Engineering Service

* * * *

"(v) The following resolution moved by Rai Sahib Fatah Chand and seconded by Mr. Adke was passed.

"The Council recommends that the Government of India be requested to suggest to Provinces that they should provincialize the Engineering Staff of the District Boards at once and bring them into a common cadre."

"(vi) In the meantime, it was suggested that in view of the fact that in most provinces the engineering staff in the Provincial cadres were not sufficient to undertake the war work and inescapable civil work, which the provinces had been asked to complete, and since it had been stated, District Board Engineering staff in many areas were not fully employed, Chief Engineers of Provinces should take action under their existing rules, in the general interests of the country, to employ District Board Engineering Staff more fully on war work. This could, in some cases, be done by doubling up some of the existing District Board charges, and employing the released men, engineers, overseers, accountants and clerks, directly under the Chief Engineer. Chief Engineers were requested to explore more vigorously than in the past the possibility of making fuller utilization of the engineering resources of their provinces."

8. The defects of the existing system of administration (except in Madras) may be summed up as arising from the following causes :-

(i) The District Local Boards enjoy autonomous powers but public opinion is not sufficiently educated to control them and the provincial Governments have ceased to exercise control ;

(ii) being small units, there is no general policy of development of roads, on a provincial basis, each unit having only parochial interest. This has resulted in a lack of balance in road development ;

(iii) undue interference by members, nepotism, and misuse of the power of letting contracts ;

(iv) want of proper control by the Dt. Board Engineer whose tenure of office is entirely dependent on his humouring the President, and the Board, without any interference or right of appeal to a higher tribunal ;

(v) appointment in many cases of incompetent, inefficient and unqualified District Engineers ;

(vi) want of sufficient funds, for proper maintenance—funds derived even from the users of roads and for the road (road cess etc.) diverted for other services. The Provincial Governments have no powers to enforce adequate utilization of funds or do not exercise these powers.

(vii) want of direction and guidance in technical matters by experienced senior engineers ;

want of sufficient control by the Provincial Governments, even over the funds contributed by the Province for roads.

9. (i) It is sometimes argued against the proposal endorsed in the Nagpur Report and discussed in this note, that the taking over of roads by the Provincial Governments will leave the District Boards with other obligations requiring the employment of engineering staff which they will not be able to undertake if they are not also responsible for "roads". These works consist of the construction and maintenance of educational, medical, sanitary and Public Health and Public utility buildings, such as schools, hospitals, protected water supplies, wells, markets, etc.

(ii) The Nagpur Conference discussed this question and the general opinion was that something like the Madras system suitably modified and improved would perhaps be the best solution of the difficulty. It may be mentioned that other services such as, Sub-assistant and Assistant Surgeons, School masters, Health staff, etc., though paid by the District Boards, are not under their entire control, but under the control of Provincial inspecting officers and the Provincial heads of Departments, such as the Director of Public Instruction, the Surgeon-General, the Director of Public Health, etc. There is no reason why a similar procedure should not be adopted in the case of Engineering staff.

(iii) At the I.R.C. meetings, however, some of the District Board Engineer delegates have consistently argued for going back to the pre 1917 system.

IV. Solution.

10. (i) The following suggestions are, therefore, for consideration :—

(a) The P.W.D. may take over residual works in addition to the Roads including staff and relieve the District Boards of all responsibility for "works".

(b) Some staff should be left with Local Bodies to look after the residual works.

(c) To follow the existing practice at Madras, whereby the staff is provincialized and under provincial Governments' control regarding discipline, promotions, etc., but carry on the works sanctioned by the District Boards, with sufficient superior inspection by higher technical personnel and greater co-ordination.

(ii) Proposal (a) would practically mean closing down the District Boards as at present constituted as they would become merely advisory bodies. In spite of the general deterioration in the matter of communications, and other inherent defects, the Boards have been doing useful service to the country in the matter of education, sanitation, medical relief, and public health. Association of local opinion is necessary for constructive development and for general advancement. Lacking local interest, the P.W.D. officers are likely to neglect small works in remote places. This proposal will meet with general public opposition; and will not, it is presumed, be acceptable. The

P.W.D. do not also have sufficient executive and supervisory staff to manage the widespread work that they would have to undertake.

(iii) Proposal (b) may also not work well. The evils of the existing system would continue in a more restricted scale with even less competent staff and there would be no progress in other useful utility services.

(iv) Proposal (c) has already proved useful and effective in Madras and, with the improvements now under consideration by the Madras Government and others that might be suggested, there should be a further increase in efficiency. There would be a Highway Department with a Chief Engineer in charge of communications, and inspectors of works, in the rank of Superintending Engineers. The staff including Dt. Bd. Engineers, Assistant Engineers and overseers would be in a provincial service under the administrative control of the Chief Engineer. Main roads would be taken over by the Provincial Government and maintained by them. The District Board would have a small technical staff, with an Assistant Engineer and some overseers also lent from the Provincial Service and working under the general direction and technical control of the Dt. Engineer on such Dt. Board works as the maintaining and constructing of minor roads and other public utility works. It would also appear that this scheme will be more acceptable to Local Bodies. With sufficient safeguards, the difficulties of dual control could be completely avoided.

11. This parallel organisation will not, even in the beginning, mean waste. With a large programme of development in the post-war period, of roads, irrigation, etc., even the existing P.W.D. and Dt. Board staff will have to be considerably augmented, and it will be found more efficient and economical to have separate departments for carrying out the different development works. All the roads now maintained by the P.W.D. should be handed over to this new Highway Department. Later, when time is ripe, the departments may be amalgamated under a common service and cadre, with possibilities of transfer from one sphere of activity to another.

12. Side by side with the provincialization, well-defined rules regarding contracts, selection of works, etc., are to be made by Provincial Governments and a lead may be given by the Central Government in suggesting model rules for adoption by Provinces.

13. There is not likely to be any financial difficulty. The present expenditure on establishment by the several district boards can all be pooled together and placed in a central fund. The revenue that is now derived from the road users and road cess may be taken over by the Provincial Government. With a large

road programme ahead, no financial difficulty for meeting the establishment on this new Highway Department is anticipated. Being relieved of the major expenditure on roads, the Dt. Boards will be able to devote greater attention and money to other services.

14. In the Provinces or areas where the District Board services are far too small to merit any separate organization, the P.W.D. may amalgamate the District Board staff and provide suitable officers for the District Boards from their staff.

V. Implications.

15. *Delegation of powers to staff.*—This requires careful examination of the existing Local Boards Act, to see to what extent this can be done and what modifications are necessary to permit of reasonable delegation. Generally most of the delegations can be made under the rule-making powers of the Provincial Government.

16. *Levy of Cesses (Road).*—Under the existing system the Local Boards have the power to move the Government to levy special cesses for road maintenance and development. If the Local bodies are relieved of this obligation to maintain the roads, the cesses will have to be given up, and the Provincial Government should have these powers, or meet the road bill from the general revenues (access), and from other taxes from users. Similarly the taxes now levied by District Boards under their rule-making powers on road transport will have to be taken by the Provincial Governments. Legal implications as to who should impose these cesses and taxes, and the apportionment for roads (access) and other services require careful examination and some workable formulae have to be fixed. These are to be determined by a study of past enactments, etc.

17. Implications regarding the conditions of service, provident fund, and other existing obligations which the Provincial Government will have to take over have also to be considered and workable solutions arrived at in pursuance of the new policy.

18. Similar implications involved by the control (technical and administrative) by the Provincial Governments also need examination and clarification. All possible future friction has to be foreseen and suitable remedial measures should be devised.

VI. Association of Local Bodies with the Road Policy.

19. With the proposed taking over the "roads" from District Boards, there may be a feeling that there would be lesser association of these bodies in the general road policy. This has to be guarded

against, by setting up suitable consultative bodies whose recommendations should receive very careful consideration. In every advanced country, public opinion and criticism are essential for progress, and unless this is secured, the administration will soon become wooden and inelastic and in course of time inefficient. The aim is to provide greater association with the public, and hence, the administration should, in all its activities, and new policies have the fullest confidence of the public. *We do not wish to dissociate ourselves from public opinion but take the public with us.*

20. Methods of securing this have to be carefully planned. We have Provincial Road Boards, who scrutinise all new road schemes, before these are taken up. Similar consultative and advisory boards will have to be set up for each District Board, with adequate representation of road transport interests and interests of other transport services such as the Railways and Waterways.

21. Sufficient scope should be provided for public criticism. The schemes for new road works should be published in the Press even in the initial stages, and all constructive criticism should be considered. Adequate rules would have to be framed to secure this.

II. MINUTES OF THE TWENTIETH MEETING OF THE COUNCIL held at BOMBAY FROM the 25th TO 28th MARCH 1944.

Present.

1. Mr. J. Vesugar, President,
2. Sir Kenneth Mitchell,
3. Mr. A.W.H. Dean,
4. Mr. N.V. Modak,
5. Mr. H. E. Ormerod,
6. Mr. G M. McKelvie,
7. Lt.-Col. John Chambers,
8. Mr. B. St J. Newton,
9. Mr. L. A. Freak,
10. Mr. W. H. E. Garrod,
11. Mr. W. L. Murrell,
12. Mr. M. K. Jadhav,
13. K. B. J. R. Colabawalla,
14. Mr. U. J. Bhatt,
15. Mr. S. R. Mehra,
16. Mr. Ali Ahmed,
17. Mr. M. A. Mirza,
18. Mr. Dildar Hussain.
19. Mr N. M. Chinoy,
20. Mr. W. J. Turnbull,
21. Mr. Ian A. T. Shannon,
22. Mr. T. R. S. Kynnersley,
23. Mr. I. C. Chacko,
24. Mr. N. A. Khot,
25. Mr. B. V. Vagh,
26. Mr. A. S. Adke,
27. Rao Bahadur A. L. Rao,
28. Rai Sahib Fateh Chand,
29. Brigadier H. N Obbard,
30. Mr. K. S. Raghavachary, Secretary.

The following Members attended by invitation :—

1. Mr. G. D. Daftary,
2. Mr. E. T. Roch,
3. Mr. C. J. Fielder,
4. Mr. M. Anwarulla,
5. Mr. E. P. Nicolaides.

PROCEDURE

The Council met at 11-00 hours on the 25th March 1944 in the Electric House, Bombay, and the proceedings opened with an informal discussion. The session was formally opened by Mr. G.F.S. Collins, Advisor to H. E. the Governor of Bombay at 12 noon.

A group photograph was taken, and after Mr. Collins left, the general discussion started in the morning was continued.

In the afternoon, the Council members were shown round works of interest in Bombay City by Mr. N. V. Modak, City Engineer, Bombay Corporation. A brief description of the items inspected is given in Appendix A. Full details were given in a note prepared by Mr. Modak and circulated to Members.

The various Sub-committees met on Sunday, the 26th March, and some of the meetings were continued on the 29th March. The Council itself met again on the 27th and 28th March from 10-00 hours to 18-00 hours.

BUSINESS

The Council session was formally opened by Mr. G.F.S. Collins, Adviser to H.E. the Governor of Bombay, at 12 noon. In welcoming him, Mr. Vesugar, the President, said :—

On behalf of the Council of the Indian Roads Congress, I would like to thank Mr. Collins for his presence and to welcome the visitors at the opening of this session of the Council. Their presence is indeed a very encouraging sign of the interest taken in post-war planning, one of the foremost planks of which must be communications.

The Indian Roads Congress is a Society whose members are qualified engineers connected with roads, and other scientists or technicians connected with road construction. The object of the Society is to promote the science and practice of road building, to provide a channel for the expression of collective opinion, to promote standardization, to advise regarding education, experiment, and research, and to hold periodical meetings for discussing technical papers. For the progress of road science, the last function is perhaps the most important. At the full sessions of the Congress advantage is taken of the large numbers present to devote the maximum time to the discussion of such papers, and this leaves very little time for the other objects of the Society. These are hardly less important and they require study and detailed discussion at smaller conferences. A good deal of the advisory and constructive work of the Congress is, therefore, carried out by the Council and its Sub-committees.

The full session of the Congress last October enjoined the Council to meet within six months, preferably in Bombay. Bombay has always been known for an enlightened and critical public opinion and it was felt that members would get the opportunity of meeting experienced men distinguished in their particular sphere to exchange views, and to get new ideas. Also it was hoped, if I may be pardoned for saying so, that a road-meeting in Bombay might lead some day to the filling of certain gaps in the road system of this Presidency. This city is also the headquarters of the Indian Roads and Transport Development Association which has demonstrated in a very practical manner its interest in road planning, by carrying out two Pilot Surveys.

Before I proceed further I must refer to the great loss sustained by the Indian Roads Congress and especially by its Council in the death of Mr. D. Nilsson, a well-known and popular citizen of Bombay, and for many years Chief Engineer of Messrs. Gammon and Coy. Mr. Nilsson was one of the founder members of the Congress and served prominently on the Council and its various Sub-committees, he read many papers and his contributions to discussions displayed engineering criticism of a high order. He made a generous donation to make the Congress a subscribing member of the British Standards Institution; he was a brilliant designer himself and brought out the best in others. We shall greatly miss his genial but firm personality at our meetings and the benefit of his advanced technical ability.

The last six months have been a period of great activity amongst those interested in road development. The Gwalior session of the Indian Roads Congress may justifiably be said to be the point at which this revival of interest became manifest. Further evidence of increasing interest is to be found in the keenness shown and in the extent and the nature of the discussions at the Technical Sub-committee meeting held in Calcutta and the Soil Research Sub-committee meeting held in Lahore.

The outstanding event in road matters of recent times has been the Nagpur Conference. The Chief Engineers of various provinces

have made a unanimous and comprehensive report on the problems ahead of us in post-war road development. That the weight of this report is recognised by Government is shown by the decision to make it available to the public. Consideration of some aspects of this report forms part of the agenda of this meeting.

The most far-reaching recommendation of the Nagpur Conference was that relating to the formation of a Road Board, a recommendation also made by the Indian Roads Congress at its Gwalior session. This proposal was made by responsible men, for long connected with road building and administration in India, as the best means of projecting and carrying out an energetic road policy through the length and breadth of the country. To what extent Provinces and States will delegate some of their authority to such a Board will depend on the confidence placed in the Board, their faith in its capacity and on their realisation of the extent of the benefit to be derived by such voluntary delegation. It may be useful to quote the instance of the Tennessee Valley Authority, in which case a central authority, with autocratic control literally worked miracles within seven years in improving the status of what was previously a bankrupt community.

A further recommendation of the Nagpur Conference was that the project estimates should be ready by August this year and that the first phase detailed estimates should be available by the end of the year. These dates were laid down by the Conference with the realisation that there must be a time lag between the submission of the estimates and the projection of the fully considered plan. It is unfortunate that there appears to be little chance of these dates being adhered to by most provinces and it should be one of our tasks to bring this recommendation of the Nagpur Conference to as early fruition as possible.

There is a blank in the Nagpur recommendations regarding finance. As practical optimists, we decided to recommend the minimum road development that would meet the future estimated requirements of India for the next 20 years; having set this limit, we did not consider finance. The most practical assistance that economists and financiers can give Government in their efforts to forward road development would be in investigating the methods and the economics of raising the necessary finance. That this can only be by loans, there can be little doubt; the only doubt is how much of these loans shall be redeemable and to what extent and in what period. In the past, road improvement and construction has been entirely from revenue. This policy has been defended as a "pay-as-you-go" policy. To pay this out of current taxes in any one year is not a "pay-as-you-go" policy but on the contrary it is a "pay-before-you-go" method of highway finance. On the other hand posterity should not be asked to pay for improvements that have become outworn or obsolescent; this would be a "pay-after-you-have-gone" policy. It is in striking the correct balance that lies the key to the problem.

Another blank in the Nagpur report, as it may appear to some, is the absence of any recommendations for "guarded motor ways," *Autobahns* as they are called in Germany and "Free-ways" in America. I am afraid it will be many years yet before there is any general demand for free-ways in India, but in two places a definite need for them already exists. The existing Grand Trunk Road out of Calcutta is only grand in name, in effect it is no better than a narrow tortuous street through the mill area. The main artery from the largest city in India should be a broad modern "free-way" with properly designed entrances and exits at a specified number of points. Similarly, in the case of Bombay, four National Highways from the North, from the North-East, from the South and from the South-East will converge just beyond Thana; from this point there should be an "autobahn" into Bombay.

Before requesting Mr. Collins to open the session, I would like to thank the members who have gathered here, many of whom have come long distances and at considerable personal inconvenience, when it is difficult to borrow the time from one's normal duties and when travelling is not very pleasant. I would like also to thank our hosts and friends in Bombay for this opportunity of exchanging views between road technicians and road users, between engineers and financiers, and between public servants and public men. In asking you, Sir, to declare this meeting of the Council open, may I express the hope that this will be the beginning of similar meetings in other cities of India with the same friendliness, the same co-operation, and the same opportunities to learn from each other.

Mr. Collins in opening the session said:—

I am very sensible of the honour to being invited to open this session of the Congress, and on behalf of the Government of Bombay, I offer it a warm welcome to this city. His Excellency the Governor has unfortunately been prevented from opening this meeting as he had intended to do.

It is clear that on no previous occasion has this Council met under such favourable auspices and this has added to Bombay's good fortune in the selection of this venue. It coincides with the dawn of a post-war reconstruction programme. It follows closely on what will be known as the Nagpur Conference which should make history as the first announcement of a comprehensive road programme for all India,—a programme so clear as to command universal acceptance. And His Excellency the Viceroy has voiced the opinion, more recently endorsed by this Government, on the first priority of roads for India's future. Well therefore may this Council feel that, though it may have appeared to be beating the air in its annual propaganda and Cato-like insistence on the value of roads to those who will not hear, its labours have after all not been in vain.

I yield to none in my conviction that roads are the starting point of all progress. It is not only that the rural population is thus in contact with the outside world to the consequent improvement of its agriculture, health, education, and general prosperity. More important is the approach from outside to the villages. I would go so far as to say that, once roads exist, those other improvements follow automatically with less expenditure to the tax-payers. Not only does the desire for villagers follow spontaneously, but those who will visit the villages and are already attracted to schemes of rural improvement, but are unable to give practical effect to their ideals by lack of personal touch, will also come forward to contribute to them. The desired progress will thus to a large extent be achieved without the impetus of a paternal Government, and in many cases without so large an expenditure of public revenues. I believe there are some who think that once the villager is provided with his school and other requirements for better living, he is happier in his splendid isolation far from the madding crowd's ignoble strife, but this is no longer within the sphere of practical politics in an agricultural country where the fullest co-operation between the urban and rural population is necessary for modern progress.

I believe this Government has in the past been regarded by this Congress and allied bodies, if not as a villain of the piece, at any rate as unreceptive to the insistent call for better roads. If so, it is turning over a new leaf. The upper ranks of the Public Works Department are being strengthened and a staff of one Superintending Engineer and four Executive Engineers is already engaged in planning road and irrigation projects. It is perhaps early to forecast an exact programme of completion, but it would seem that, while National and rovincial

highways and more important district roads need immediate improvement throughout the Province, smaller district and village roads should be largely the subject of a concentrated programme step by step in selected areas so as to cover the whole Province as early as possible. To give two instances, the recent land improvement in Bijapur demand the consequent improvement of marketing facilities and the bravery of the Maratha soldiers deserves the early improvement of communication in a district like Ratnagiri. In this respect the recent *pilot schemes* of the Indian Roads and Transport Development Association will be an inspiration.

Introductory speeches should be brief in a session which I have shown affords so much scope for practical results. I now therefore have great pleasure in declaring it open and in wishing you success in your deliberations.

2. The proceedings opened with an informal discussion on the business set out in the Agenda. During this discussion, Mr Dean obtained permission to bring forward a suggestion that an engineer of eminence with special knowledge and experience of post-war planning should be invited to visit India to stimulate engineering thought and awaken interest in engineering generally in this country. The Government of India recently invited Professor A. V. Hill, a Secretary of the Royal Society, to advise on Scientific Research and Development and this scientist has, to common knowledge, enabled scientists from all over the country to get together, discuss problems, and plan for the future. Through him, scientific thought and achievement in India has been linked with that of the outside world and a new stimulus to and a new orientation of scientific effort in this country in defined channels is already apparent.

3. In Mr. Dean's view this was an opportune time to invite an engineer of eminence from abroad to give us first-hand information on current engineering practice in other countries and to provide a focal point and a stimulus for engineering discussions and planning here. With a potentially large post-war development programme of road construction in this country, we should know the lines on which others with similar programmes are planning and the methods they propose to adopt.

4. The suggestion led to a lively discussion. The following resolution was passed :—

This Council recommends that in view of the large expenditure contemplated in the post-war period, the Government of India should :—

(i) *Invite immediately an engineer of eminence from abroad to visit India for a period of six months to one year to advise on methods of organization, planning, construction and research.*

(ii) *Send abroad three or four officers of ten to fifteen years' experience for a period of one year or so, to study current practice in—*

(a) *concrete and black top road construction.*

(b) *soil mechanics.*

(c) *bridging, and*

(d) *research and research organisation, statistical research, and the setting up of research stations.*

Each officer to specialise in one subject. The officers should be sent at once, be back in India by the time the post-war road development programme is to start, and be available for this work.

(iii) *Send abroad, on the analogy of the Bevin Scheme, several batches of selected young officers between 28 and 35 years of age to obtain general experience and knowledge in all branches of road and bridge theory and practice.*

5. Confirmation of the Minutes of the Nineteenth Meeting of the Council.

These were taken as read and confirmed.

6. Executive Committee of Council.

(i) The Council ratified the action of the President in constituting an Executive Committee and calling an emergent meeting of this Committee in February 1944.

(ii) The Council approved the Minutes of the meeting of this Executive Committee held on 12th February 1944.

(iii) The Council appointed the following members to form an Executive Committee, till the next General session of the Congress :—

(1) Mr. J. Vesugar	..	President
(2) Mr. A. W. H. Dean	..	Vice-President
(3) Mr. N. V. Modak	..	,,
(4) Mr. H. E. Ormerod	..	,,
(5) Mr. G. M. McKelvie	..	Honorary Treasurer
(6) Mr. K. S. Raghavachary	..	Secretary.

7. Report of the Nagpur Conference of the Chief Engineers on Post-war Road Development and Report of the Technical Sub-committee to the Subject Committee on

Transport, on the future of Road Transport and Road-Rai Relations.

(i) In view of the comprehensive and authoritative natur of these reports, it was proposed that the Executive Com mittee should study them and report to the Council in du course, but in the meantime, taking advantage of a meetin of the Council, the highlights should be discussed.

(ii) The Council thought that as roads, road transport and transport in general necessarily played a major part i the country's internal economy, and road engineers had bee so largely responsible for the construction of roads and stud of road transport problems, they should be able to mak some useful contribution to the way in which the variou forms of transport, which had become rivals in recent years could be employed to the best advantage of the community There was some divergence of opinion as to whether th Council, as representing the Indian Roads Congress, shoulc comment at this stage on a subject which inevitably raise political issues upon which they are not necessarily a authoritative body but, as the Government of India hav published the two Reports, thereby inviting public opinio on them, it was felt that it would be of value if the admi nistrations concerned were informed of the first impression of the Council on the Reports and, later, of the results of a more detailed study.

(iii) Various delegates described the difficulties they wer experiencing with regard to *planning* in the absence o authoritative guidance from the Centre on details of policy For example, the road system to be adopted in particula areas depends on whether certain bridges are to be construct ed or not. The position of certain main bridges in som provinces depends on the routes selected for Nationa Highways and these again depend on the routes selected fo strategic reasons and the routes preferred by neighbouring provinces. Bridges over large rivers form focal points, anc inevitably fix the road system. On the other hand, should it be decided as an alternative to run two or more ferries, the road system would be entirely different. Landing craft suitable for use on ferries will be available in large numbers after the war and this fact will also affect general planning.

(iv) The frame of National Highways on which several Provincial Governments intend to express their opinion has also to be finally fixed before the subsidiary network of provincial and local roads can be planned and the question is also to be decided whether certain railway bridges are to be decked or otherwise made available for

road traffic, thus forming focal point, or whether means of crossing large rivers are to be adopted.

On all these points, authoritative advice from the Centre is required.

(v) After a discussion which brought out many other practical difficulties in planning a road system of India, the Council adopted the following resolution:—

This Council reiterates its recommendation that the early formation of a Road Board is necessary and is of the opinion that the creation of a single post of Planning Officer for post-war road development is not sufficient since Planning in Provinces and States cannot proceed until far-reaching decisions are taken on many details by an authoritative body such as the proposed Road Board.

8. The Council recorded the following views for consideration by the Executive Committee when studying these reports:—

I. THE NAGPUR REPORT.

(i) In view of the very heavy expenditure to be incurred on works in the suggested road construction and improvement plan, it is essential that the staff chosen for working out the plan should not only be adequate in numbers but should consist of the best men available for the purpose. It is recorded that the Federal Highways Administration Act of the U.S.A. allowed 3 per cent. of the total Federal expenditure on roads to be retained for Federal administration, planning and research. Although not suggesting that as much as Rs. 13½ crores should be set aside for this purpose in the case of the Indian post-war road development plan, the Council feel that funds should not be grudged to provide a Central organisation which would command the respect and confidence of the Provinces and States and that the Planning Staff throughout the country should be capable of giving effect to the directions of the Centre.

(ii) With reference to para. 17 of the Nagpur Report, the Council emphasised the necessity for planning *now* for essential segregation of traffic and the provision, in the earlier stages of development, of cycle tracks, and pathways for pedestrians wherever necessary for public safety and convenience. This provision should be an integral part of the plan and not left as an after-thought or to be financed from contingencies.

(iii) With regard to financing the road development plan, the Council endorsed the recommendations of the Nagpur Conference that the Country cannot afford to neglect road communications any longer and that the major portions of any increase in revenue directly attributable to road communication should be hypothecated to road development (amortization of loans etc.); and further that the question of taxing the users of and those who benefit directly from roads should be thoroughly examined.

In support of this the Council draws attention to the fact that in India an impression exists that the general taxpayer pays for the roads for the benefit of motorists. On the contrary in the years immediately preceding the war, the total contribution to revenue from motor taxation including import duty on motors and accessories, registration fees, and tax on petrol together exceeded by 50 per cent. the amount spent annually on construction and maintenance of roads by the Centre, Province and States.

Comparative figures are given below:—

Country	Motor taxation.	Tax per motor vehicle.	Expenditure on roads
India	Rs. 9 crores (1939)	Rs. 509/-	Rs. 6/- crores (1939)
U. S. A.	Rs. 162/- „ (1935)	Rs. 47.6/-	Rs. 302/- „ (1935)
U. K.	Rs. 78.5/- „ (1934)	Rs. 262/-	Rs. 80/- „ (1934)
France	Rs. 36.5/- „ (1932)	Rs. 212/-	Rs. 53.6/- „ (1932)
Germany	Rs. 46.3/- „ (1930)	Rs. 222/-	Rs. 48.3/- „ (1934)

These figures refer merely to the revenue emanating from the use of the road by motor vehicles road users. Taxation of gainful use of the road by other methods of transport and the betterment effected by road construction may be examined with a view to its contributing to road finance.

(iv) A statistical survey of road and road traffic conditions in India should be undertaken at once under the direction of the Central Government with a view to standardising road practice under different conditions of local resources, traffic, and climate, and to working out probable traffic densities and road requirements of different areas during the next 20 years after the war.

(v) The Council endorsed the recommendation in paras. 86—88 of the Nagpur report, that all road work should be taken over under P.W.D. control and that Local Board Engineering staff should be provincialised under the control of the Chief Engineer of the province or administrations concerned and their terms of service

brought into line with those of the corresponding P.W.D. staff having due regard to individual qualifications, service, and experience. The Educational, Medical, and Puplic Health District Board staff are, it is understood, in many provinces under the direct control of the respective provincial heads of those Departments and the Council considers that an exception should no longer be made in the case of Engineering staff. The Council considers further that the question of how best to execute the remaining district Council and Local Board Works should be examined by Provincial Governments. To assist in this matter, the Executive Committee of the Council will examine this subject in consultation with members of the Indian Roads Congress and make recommendations as soon as possible.

ROAD TRANSPORT AND ROAD-RAIL RELATIONS REPORT

(vi) The Council endorses the recommendation that the object of any transport policy must be to provide and develop cheap and efficient transport for all by the means best suited for the kind of traffic involved, with due regard to the public interest and without favouring any one means at the expense of another; and furher that the interests of individual producers and users of transport must be subordinated to the interest of the community.

(vii) The Council is taking steps through members of the Indian Roads Congress to experiment with improved type of bullock-carts and as a further step it proposes to build oxperimental carts using motor vehicles parts placed at its disposal by the Army Disposal Board. It recommends that Provincial and State Governments should do all in their power to encourange the use of improved types of bullock-carts.

(viii) The Council endorses the recommendation that long distance carriage of goods by roads must be regulated in accordance with the public need, and in the light of alternative facilities. It agrees that there has been no road planning in the past in India and that the evolution of road administration has been on the assumption that roads are suitable for devolution. This policy has had bad results: there has been no expansion and improvements commensurate with the growth of population, and the movement of commercial crops. For social, political, and economic progress, the development and

maintenance of a national Highway system, and the control of traffic on this system, (which will carry all the long distance traffic) should be directed by the Indian Road Board.

(ix) The Council considers that not only should arrangements be made for the maintenance of reliable statistical information on all transport matters but that comparative statistics of other countries should be collected, maintained, and studied as this will enhance the value of statistical information collected in this country and ensure that it is recorded in a proper form (as has not always been the case in the past).

(x) The Council endorses the recommendations :—

(a) that controlled monopolies on light traffic routes should be permitted,

(b) that a scientific review of motor vehicles is necessary,

(c) that general review of taxation of all forms of transport is urgently required,

(d) that alternative forms of fuel should be encouraged. This should, however, be done by subsidies rather than by differential taxation,

(e) there should be a whole-time Transport Commissioner in each province,

(f) that Indian States should in due course be associated with the evolution and administration of a uniform transport policy.

(xi) The Council feels that one of the most important recommendations in the report under consideration is that there should be a Central Transport Budget for Road-Rail Transport as a whole. An Expert Committee to examine this question should be appointed as early as possible. It suggests that the question of extending this principle to include all forms of Transport namely road, rail, air, inland water, and coastal shipping should be examined by the same Committee.

9. The following resolution was passed :—
The Council in support of its proposals for the formation of a Road Board and Advisory Council recommends that control be exercised by a Ministry of Transport or some such body, over all forms of transport, including Road, Rail, Coastal Shipping, Inland Water, and Air transport

to prevent unhealthy rivalry and cut-throat competition, and with the object of obtaining the best out of all forms of transport in the interests of the country.

10. The Council records its appreciation of the action of the Government of India in publishing these Reports thereby inviting public opinion on matters of communication and transport, subjects in which the public is vitally interested.

11. Appointment of Sub-committees.

(i) The Council accepted the duties assigned to the Indian Roads Congress by the Chief Engineers at their Nagpur-Conference.

(ii) It was agreed that no Sub-committee should generally have more than five Members, that one Member should assume responsibility for the business of the Sub-committee and act as convenor and that each Sub-committee should submit its report to the Council at least a month before the next meeting.

(iii) The following Sub-committees were re-constituted :—

(a) **Bullock-cart—**	Messrs. Murell (convenor), Newton, Dildar Hussain, Vagh.
(b) **Soil Stabilization—**	Messrs. Dean (convenor), Freak Mehra, Bhatt, Vaidyanathan.
(c) **Education—**	Messrs. Modak (convenor), Anwarullah, V.N. Rangaswami, Kynnersley.
(d) **Bridges—**	Messrs. McKelvie (convenor), Chambers, Nicholaides, Cochrane.
(e) **Sir Kenneth Mitchell Fund—**	Messrs Dean (convenor), Chinoy, Modak, Ormerod.

(iv) It was agreed that the existing *Technical Sub-committee* which has 15 Members is too big and that it should be split up into Sub-committees for *Specifications, Test Track, Road Transport, Research* and other subjects as necessary. The President should nominate Members for these Sub-committees from a panel consisting of the existing 15 Members and such others as have a special interest in the subjects to be studied.

12. Resolution passed by the Gwalior Session of the Congress on Road Development and creation of a Road Board.

(i) This resolution was forwarded to the Government of India on 18th October 1943 and the Congress was informed that the matter was receiving attention. The

action so far taken by the Government of India, as known to the public, is to release for publication the Reports referred to in paragraph 7 of these Minutes. It was explained to the Council that as "roads" is not a Central subject, the Government of India cannot take full action as proposed in the resolution of the Congress without first consulting and obtaining the concurrence of the Provinces and States and this is being done.

(ii) It was decided that as one of the objects of the Indian Roads Congress is to provide a channel for the collective opinion of its Members on matters affecting roads, the opinion of the Governing Body as representing the Members and as recorded in these Minutes should be communicated to all Provincial Governments and the Governments of the more important States.

13. Reprinting the Memorandum of Association of the Indian Roads Congress and its Regulations and Bye-laws (which are now out of print) and consideration of proposed amendments.

(i) The Council generally agreed to the proposals suggested and authorised the Executive Committee to issue a *provisional* reprint subject to ratification at the next General meeting of the Congress.

(ii) With regard to the suggestion that Transport interests should be associated more closely than before with the Indian Roads Congress, it was decided that the non-official Members of the Council should form a Sub-committee to suggest ways and means of implementing this proposal.

(iii) It was agreed, subject to confirmation at the next General meeting, that Members of the Society co-opted to the Council should have full voting powers.

(iv) It was agreed, subject to approval at the next General Meeting, that the entrance fee should be the same as the subscriptions for Members and that this fee and the subscription for Associate Members should be Rs. 100.

14. Report of the Secretary on the working of the Indian Roads Congress Office.

(i) The Council agreed that the expansion in the Indian Roads Congress office contemplated at the Gwalior session is hampered because of lack of funds and that the work which it had agreed to undertake as outlined in paragraph 11 of these Minutes could not be done unless the office was considerably expanded.

(ii) There was a lively discussion on ways and means of increasing the revenue of the Society. It was urged by some members that under item 2 (f) of its Memorandum of Association, the Society could accept subscriptions, donations, endowments, and gifts in furtherance of the object of the Society" and that trade interest and sister Associations had been informally approached and were prepared to make substantial donations to the Society.

(iii) It was agreed that there were objections to accepting such donations and that Government of India should be approached to make a lump sum donation of Rs. 25,000 during the current year and to increase the annual subscriptions to Rs. 20,000 for the present, since many of the activities which the Society performs are of direct benefit to Government. It was considered preferable to approach Government in the first place rather than "to go round with a begging bowl" asking for donations and gifts.

(iv) The Executive Committee was authorised to appoint an Assistant Secretary in anticipation of provision of funds to meet his salary, and to pay for such assistance and help as the Secretary might require in carrying out the business of the Congress.

15. Reports of Sub-committees.

(i) All the Sub-committees met at Bombay on Sunday the 26th March. Their reports will be examined by the Executive Committee and submitted for consideration at the next meeting of the Council.

(ii) Certain instructions were given by the Council to various Sub-committees.

16. Proposed resolutions regarding District Boards.

(i) The resolution regarding provincialization of the Service of District Board Engineers is dealt with for the main part under item 8 (v) of these Minutes. It was decided that to give effective support to the principle underlying the resolution (which the Council approves), it will be necessary before submitting a further formal resolution on the subject to the Provincial Governments, (the Governments concerned), to study the full implications of the proposal and devise means of giving effect to the change since the Council is not satisfied that an unmodified acceptance of the Madras precedent would be in the public interest. The Executive Committee will draw up a note on the subject and consult Members interest-

ed before the next meeting of the Council when the proposals will be further discussed.

(ii) Resolution regarding unspent balances of road funds lying with District Boards.

(a) Several Members brought to the notice of the Council that, owing to the present condition of shortage of supplies, high prices and difficulties of transport, road maintenance was being neglected in many places, and particularly in the case of District Boards, the funds ordinarily reserved for this purpose were being diverted to other objects. The proposer of this Resolution stated that his own Provincial Government had issued an order that funds earmarked for Education should not be diverted to other purposes in cases where there was a delay in carrying out educational schemes but should be reserved and spent at a later date on the schemes for which they were originally allotted. He suggested that Provincial Governments should be asked to issue similar orders regarding funds ordinarily allotted for communications.

(b) It was generally agreed that due to war conditions there were serious gaps in road maintenance in many areas. The Council agrees with and amplifies the recommendation made in paragraph 72 of the Nagpur Report, viz., that the authorities responsible for communications should be prepared to accept an increased liability for maintenance over pre-war costs in the ratio that current costs bear to pre-war costs. It was suggested that the Congress should recommend that the Government of India when distributing Road Fund and other grants from the Centre, should take into account any neglect of maintenance and diversion of funds from communications on the part of Provinces and States and that these administrations should similarly take into account similar diversions made by local bodies. This would follow the practice adopted in the U.S.A. where the Federal Aid Act provides a penalty for excessive diversion of funds from Highways.

(c) The following Resolution was passed :—

The Council views with concern the serious gaps apparent in the road maintenance and programme in many areas. It realizes that owing to war conditions of short supplies, high prices, and transport shortage, it is difficult

to ensure proper road maintenance but it is seriously concerned with the greatly disproportionate wastage in the road assets of the country which neglect of maintenance will entail. The Council endorses and amplifies the recommendation made by the Chief Engineers at their Nagpur Conference in December 1943 (paragraph 72) that all authorities responsible for the upkeep of roads should be prepared to spend on road maintenance not only the sum that was spent before the war but in addition a sum representing the difference between current and pre-war costs of executing repairs. The Council recommends that steps should be taken by Provincial Governments to prevent diversion to other purposes by local bodies of funds allotted for road maintenance. It also advises that when post-war reconstruction work is to be taken up, those administrations which have through default permitted serious wastage of their road communication assets, should not be allowed additional funds from any source provided by the general taxpayer or road users in general, to repair those locally wasted assets at the expense of administrations which have husbanded their local road assets.

17. Miscellaneous business.

(i) *Proposal to form a Chair of Highway Engineering at an Indian University.*—This will be dealt with by the Education Committee, vide para. 11 of these Minutes and item (vii) below.

(ii) *Rules for the next essay competition.*—To be considered by the Executive Committee.

(iii) *Subject of papers for the next General Session.*—To be considered by the Executive Committee who will issue a letter to all Members on the subject.

(iv) *Venue of the next General Session.*—The Madras Government have invited the Congress to the Madras Presidency with the proviso that it will not be possible to hold the session in Madras town itself or in Coimbatore.

Decided that the Session should be held towards the end of January or early February 1945. The Executive Committee to fix details.

The Secretary was instructed to thank the Madras Government on behalf of the Indian Roads Congress for agreeing to the next General Session being held in the Madras Presidency.

(v) *Scholarship for post-graduate studies in Highway engineering in Europe, America and Australia.*—Decided that the Congress itself could not afford to grant any scholarships. The subject is dealt with in the resolution recorded in para. 4 of these Minutes.

(vi) *Presentation to Sir Kenneth Mitchell.*—To be dealt with by the Sub-committee appointed under paragraph 11 (iii) of these Minutes

(vii) *Printing of certain Memoranda etc.*—To be dealt with by the Executive Committee.

(viii) *Steps to be taken to improve the technical education of the Road Engineer in India.*

The following resolution, moved by Mr. N. V. Modak and seconded by Mr. Dildar Hussain, was passed by the Council:—

> "*Resolved that with a view to implement the suggestion made by Sir Kenneth Mitchell in para. 31 of his Presidential address, on the subject of improving the Technical Education of the Road Engineer in India, this Council appoints a sub-committee:—*
>
> (1) *To draw up a Memorandum on this subject and circulate it to the various Engineering Colleges in India;*
>
> (2) *To examine the possibility of arranging evening refresher courses in Highway Engineering at selected engineering colleges for the benefit of road engineers and subordinates in service, and others such as under-graduates who wish to specialise in Highway Engineering;*
>
> (3) *To formulate a scheme for establishing a Chair of Highway Engineering to be named "The Sir Kenneth Mitchell Chair of Highway Engineering" in one of the Indian Universities;*
>
> (4) *To devise ways and means of financing the last proposal;*
>
> (5) *To investigate whether there is need to train a greater number of students than at present in engineering to meet the demand for Engineering personnel required for the planning and execution of the proposed ambitious programme of work in the post-war period, in roads, bridges, irrigation and hydro-electric schemes etc.*

The Sub-committee mentioned in paragraph 11 of these Minutes was appointed to examine the question with power to co-opt Principals and Professors of Engineering Colleges and such other experts as they consider desirable. The Sub-committee was requested to submit its report to the Council before the next meeting to be held some time in August 1944. This Committee was alo requested to deal with other questions concerning education, vide paragraphs 4 and 17 (i) of these Minutes.

(ix) *Viceroy's War Purposes Fund.*—The Secretary was instructed to address a letter on the subject to Members.

(x) *Criticisms of the Nagpur and Road Transport and Road-Rail Relations Reports* referred to in paragraph 7 of these Minutes.

(a) Some members criticised certain details of these reports. After some discussion it was decided that if these Members submitted their criticisms in writing, they would be studied by the Executive Committee so that such action as considered necessary could be taken at the next meeting of the Council.

(b) Extracts from a written criticism sent by Mr. T. Lokanathan of Madras were read out to the Council and copies were placed on the table. This criticism was further explained by Rao Bahadur A. Lakshminarayana Rao of Madras. The Secretary was instructed to reply to Mr. Lokanathan.

(xi) *Immediate appointment of a Sub-committee to draw up an authoritative specification on water-bound macadam.*

The appointment of this Sub-committee was moved by Rao Bahadur A.L. Rao who explained that recently there had been in evidence a great difference of opinion among engineers in Madras on water-bound macadam and it was desirable that the Indian Roads Congress should issue an authoritative specification.

During the discussion it was elicited that papers had already been read on this subject and printed in past Proceedings indicating the practice in the Punjab, Bihar and some other parts of India. Water-bound macadam roads have been constructed during the last hundred years in all parts of the world and their milage probably much exceeds the milage of all other types of surfaced roads in the

world put together. The principles are generally understood by road engineers but the technique differs in different areas as it depends on the local climatic and road building materials and conditions. In recent years soil stabilization has made considerable progress and it appears that some road engineers have attempted to adopt a soil stabilized specification in place of the regular macadam specification without properly understanding the difference in technique involved.

The Council agreed that it would be advisable to publish a note on the subject for the guidance of engineers and the following Sub-committee was appointed—

(1) Rao Bahadur A. Lakshminarayana Rao (convenor)
(2) Mr. Dildar Hussain
(3) Mr. A. S. Adke
(4) Mr. C. J. Fielder
(5) Mr. G.M. McKelvie.

(xii) *Regional Branches of the Indian Roads Congress.*— A proposal to form Regional Branches of the Indian Roads Congress was considered. It was agreed that such branches might be tried for the present in Madras, Bombay, and Hyderabad with the object of maintaining a more sustained interest in the activities of the Congress in areas where large number of Congress Members reside. Members interested in this proposal were asked to constitute these branches in consultation with the Secretary, Indian Roads Congress. The following rules are to be observed in the meantime by the Regional Branches. The rules may be modified by the Council after experience has been gained on their working.

(a) The policy adopted by Branches is to be the same as that of the Main body.

(b) All recommendations, resolutions etc. are to be submitted to the Governing body for approval before they are published or acted on.

(c) The Branches should keep in close touch with the Secretary of the Indian Roads Congress and send him copies of the Agenda and Minutes of Meetings, speeches, papers, etc.

(xiii) *Proposal that meetings of the Council should be held in a central place in India such as Nagpur.*

The President explained that he was endeavouring to do this but it was very difficult to get accommodation. Nagpur is not again available. The next meeting of the Council is fixed for end of August or the beginning of

September, 1944, but the venue has not yet been decided because of the difficulties stated.

(*xiv*) *Improving bullock carts by utilizing motor vehicle parts to be released by the Army Disposal Board.*

It is anticipated that a very large number of partly worn motor vehicle parts will be released by the Army Disposal Board. The following Members agreed to take action as stated :—

(a) Mr. Ormerod agreed to approach the A. C. C. to experiment with making a few bullock carts from part-worn motor vehicle parts placed at its disposal.

(b) Messrs. Shannon and Modak agreed to take similar action with regard to the Burmah Shell Coy. and the Bombay Corporation.

(c) The Bullock Cart Sub-committee promised to consider the matter.

(d) Mr. Anwar-ullah thought he might interest the Hyderabad State Government in the matter.

(e) The Council agreed to ask Mr. Trollip of B.E.S.T. Bombay to take similar action if he thought fit.

(*xv*) *Statistics showing the proportion of cost of transport to total cost of goods.*

It was agreed that such statistical information would be of great interest and value to manufacturers, traders, and the public in general as their study would indicate to what extent the public were paying for the lack of good communications, but there was no indication that such statistics were available in India. It was recommended that this matter should be studied by the Statistical Branch to be set up at the Centre.

(*xvi*) *"Dreaming is not planning."*

A paper entitled "Dreaming is not planning" was considered by the Council and it decided to do all in its power to press for a realistic approach to post-war planning. As long as plans are kept secret by the Governments concerned, they are in danger of becoming mere dreams which will vanish (or be pigeon-holed) in the light of the post-war day. If plans are made public, it will be the fault of the public, whatever be the form of the post-war Government, if they are allowed to become mere dreams. For this reason, the Council has recorded its appreciation of the action of the Government of India in

publishing the two plans dealt with in these Minutes and it will do all in its power to bring home to the public that nothing has been achieved without planning.

(*xvii*) *Post-war Transport in Great Britain.*

Extracts from a paper read before the Institution of Civil Engineers, London, and published in the January 1944 journal of the Institution, were circulated to Members. This paper discussed the formation of a National Transport Trust. It was decided that the Executive Committee should study this paper and that it should be discussed at the next session of the Council

(*xviii*) *Survey of Engineer Resources.*

Some members urged that a balanced use of engineer resources throughout the country was not being made. The engineers in the provinces most affected by the war had more work than they could well manage while in other areas, and particularly in the case of District Board Engineer staff, there was less work than in pre-war years.

It was recommended that :—

A Central survey of the ratio between engineer staff and engineer work to be (a) executed and (b) planned, should be made and proposals for the most effective utilization of the staff available be considered. The question of revision of salaries to attract the staff needed for execution of work and for planning should be examined.

18. The following resolution of condolence was passed, all members standing :—

"The Council records with a deep sense of regret the great loss sustained by the Indian Roads Congress and especially by the Council by the untimely death in February last of Mr. D. Nilsson who was one of the founder Members of the Indian Roads Congress and served prominently on the Council and several of its Committees for many years. His great ability as an engineer won him the admiration and respect of all who knew him, he was a brilliant designer himself and brought out the best in all his associates; and he was always ready to place his long experience and great technical ability at the disposal of the Congress. His genial but firm personality and burning enthusiasm will be greatly missed at the General and Council Meetings of the future".

19. The Council expressed its desire that the President should convey the thanks of the Council to Messrs. Daftary and Roch for providing accommodation for Members; to Mr. Modak for arranging a tour of inspection and other help; to Mr. Trollip for being host to the meeting; to the Bombay Electric Supply and Tramways Coy. for the use of their Conference Hall; to General Motors for their help in matters of Transport; to Mr. Chinoy for his help in transport and other matters: and to Mr. Kynnersley for his very active share and help in the arrangements.

The proceedings then ended.

Appendix A

Brief description of engineering works of interest in Bombay City inspected on 25th March 1944 by Members of the Council of the Indian Roads Congress under the guidance of Mr. N. V. Modak, City Engineer, Bombay Corporation.

(i) **Hornby Road.** Opposite the Municipal Office where sheet asphalt had been replaced for a width of 10 feet, by cement concrete 4 in. thick, (proportion 1:2:3½) to take bullock cart traffic.

(ii) **Argyle Road.**

(a) Cement concrete road constructed in 1931. Length 2640 ft., width 40 ft., thickness 8 in —1:2:3. Traffic 13,600 tons per day or 340 tons per foot width of carriageway and consisting mainly of heavy motor lorries and bullock carts. The surface although of cement concrete is badly corrugated—Annual maintenance per 100 sq. ft. 8.6 annas between 1931-37, 9.7 annas between 1937-44.

(b) A length 840 ft. width 40 ft., construction: stone sets over 6 in. cement concrete 1:3:6—year 1936-37. This portion is good. Maintenance nil so far.

(iii) **Reay Road.** Width 66 ft. with 15 ft. footpaths on either side. Daily traffic 100,000 tons or 208 tons per foot width consisting of heavy lorries and bullock carts.

Water-bound macadam was replaced by stone sets laid on cement concrete (1:3:6) 9 in. thick in 1924-25. This pavement was due for renewal four years ago, but as an experimental measure a portion has been treated with 2 in. sheet asphalt carpet. The results are being watched.

(iv) **Road Line-Painting Machine.** This is a locally made contrivance for painting lines on roads costing only Rs. 300. Daily outturn 8,000 running feet of road line. The machine is worked easily by one man; full description is given.

(v) **Road over Bellasis over-bridge.** Length 1,100 ft.; width of carriageway 40 ft. with two side footpaths 10 ft. each. Traffic mainly Victorias and motor cars. Widening of the bridge which was originally only 30 ft. wide was done in 1938-39.

The road surface consists of 2 course concrete (eleve-crete) with a cleavage plane of jute fabric 1/8 in. mesh. The bottom course is 6 in. thick (1:3:6) and the wearing coat 2 in. (1:2:3). Dowel bars 4 ft. long and at 2 ft. centres were used in the bottom foundation course.

The main advantage claimed for this type of construction is that if the top surface wears out, it can be removed and replaced by similar concrete

or asphalt carpet—the cleavage plane formed by the jute fabric enabling this to be done without disturbing the foundation concrete.

Cost of construction :- Bottom course 22-8-0 per 100 sq. ft.

Wearing course 19-0-0 „

Cost of maintenance:- Rs. 0-2-0 per 100 sq. ft. for filling up of joints.

(vi) **Delisle Road.** Present width 60 ft. with a carriageway of 30 ft. In 1929-30 sheet asphalt was laid over 6 in. thick cement concrete (1:3:6) at a cost of Rs. 12 per 100 sq. ft. (cost of maintenance Rs. 1.2 per 100 sq. ft.). The wearing coat of sheet asphalt did not last quite so well as expected, and is now being replaced by cement concrete (1:2·3½). Over the old foundation of cement concrete, an insulation layer of sand ½ in. thick is laid to enable the surface slab to slide freely while expanding or contracting due to variations in temperature.

(vii) **Keluskar Road.** Concrete road 30 ft. carriageway, cement concrete 6 in. thick laid in slabs of 30 to 40 ft in length and 10 to 15 ft. in width. The oldest portion for a length of 185 ft. laid in 1923-24, was laid in *transverse bays* 15 ft. longitudinally and 30 ft. transversely without longitudinal joints. The slabs have cracked.

Cost of construction :- Rs. 60/- per 100 sq. ft.

Cost of maintenance :- Rs. 0.2 per 100 sq. ft. (for joints).

The road is in good condition.

(vii) **Sewage Disposal works at Dadar.** These works have been constructed on modern lines. A special feature of this disposal works is the utilization of sludge gas for cooking and heating in a local hospital and also for lorry running for which the gas is compressed to 5,000 lbs. per sq. in. and filled at a pressure of 3,500 lbs per sq. in. into cylinders fitted on the lorries. A point of interest is that the output of gas from the sewage is 0.7 cu. ft. per inhabitant and 1,500 cu. ft. is required to run a ten-ton lorry fifty-five miles.

Mr. Modak also explained in detail the working of the various units of the plant and certain experiments which are being conducted on a system of disposal which is almost self-acting and requires little skilled attention and the minimum of maintenance.

CYCLE TRACKS IN EUROPE

POINTS IN DESIGN.

1. An excellent cycle track.
2. Ample space at the sides for parking, also for extending the width of the road at some later date.
3. Road signs utilising a pictorial display instead of instructions in writing. The sign on the right of the picture is painted blue indicating that the track is available for bicycles. The sign on the left of the picture shows a circle in red indicating that the vehicles and animals depicted therein are prohibited from using this particular track.

With acknowledgments to the Associated Cement Companies Ltd. Separate cycle and pedestrian tracks have been recommended in the Post-War Road Development Plan for India—*Secretary*.

MINUTES OF THE TWENTY-FIRST MEETING OF THE COUNCIL held at LUCKNOW FROM 14th to 18th SEPTEMBER 1944.

Present.

1. Mr. J. Vesugar—President
2. Sir Kenneth Mitchell
3. Mr. G.M. McKelvie
4. Mr. H.E. Ormerod
5. Mr. T. Lokanathan
6. Mr C.G. Kale
7. Lt.-Col. John Chambers
8. Mr. W.F. Walker
9. Mr. L.A. Freak
10. Mr. W.L. Murrell
11. Mr. H.K. Nivas
12. Mr. W. Lawley
13. Mr. Brij Narayan
14. Mr. F.E. Cormack
15. Mr. W.B. Calder
16. Brigadier H. N. Obbard
17. Mr. U. S. Ramasundaram
18. Mr. G. B. Vaswani
19. Mr. Ian A. T. Shannon
20. Mr. N. A. Khot
21. Mr. B. V. Vagh
22. Mr. A. S. Adke
23. Capt. N. K. Bhonsle
24. Mr. W. J. Turnbull
25. Mr. T. R. S. Kynnersley
26. Mr. Nur Mohamed Chinoy
27. Rai Sahib Fateh Chand
28. Mr. U. J. Bhatt
29. Mr. K. S. Raghavachary—Secretary.

The following attended by invitation.

1. Mr. Mahabir Prasad
2. Rao Bahadur A. Nageswara Aiyer
3. Mr. Jagdish Prasad
4. Mr. C. J. Fielder
5. Mr. P. S. Bhatnagar.

PROCEDURE

The Council met at 11-00 hours on the 14th of September 1944 in the Committee Room of the Council House, Lucknow and the proceedings opened with an informal discussion. The session was formally opened by His Excellency Sir Maurice Hallett, G.C.I.E., K.C.S.I., I.C.S., Governor of the United Provinces, at 12 noon in the presence of many distinguished visitors and officials in addition to the representatives of the Indian Roads Congress.

After a group photograph was taken, the general discussion started in the morning was continued.

On the 15th, the Council members inspected works on the Lucknow-Cawnpore Road and the Chakeri Aerodrome. (Brief details given in *Appendix B*). At Cawnpore members were very kindly entertained to lunch by Sir Padampat Singhania.

The various sub-committees met on Sunday the 17th September 1944 and some of the meetings were continued on the 19th. The Council itself met on the 16th, and again on the 18th when the executive business was completed.

BUSINESS.

The Council Session was formally opened by His Excellency Sir Maurice Hallett, G.C.I.E., K.C.S.I., I.C.S., Governor of the United Provinces, at 12 noon on the 14th September 1944. In welcoming him, Mr. Vesugar, the President, said:—

It is my privilege to thank Your Excellency on behalf of the Council of the Indian Roads Congress for the honour you have done us by your presence today. Our thanks are also due to the officers and other gentlemen of this Province, who by coming here have shown their interest in the development o. road communications. Here in Lucknow we feel we are among old friends because the Congress had already enjoyed the hospitality of this city—in February 1937 to be exact. Therefore you are fully aware what the Indian Roads Congress is, what it has done, and what it is doing.

First I shall read to you a message from Sir Edward Benthall, Member of the Viceroy's Executive Council in charge of Transport.

> "This is the first meeting of the Council of Indian Roads Congress since the subject of roads came into my portfolio—to the extent to which the Central Government are concerned in a Provincial subject. It is a very great pleasure therefore to send you my good wishes not only for this particular meeting but also for the continued vigour and prosperity of the Roads Congress in the pregnant future.
>
> "It is unfortunately not possible for me at this particular moment to make any pronouncement on policy which will capture the imagination of the Congress or the public. The earlier, and if I may say so, easier phases of planning have been accomplished and the stage has now been reached when decisions of the first magnitude have to be taken, not only in the field of road planning and development but over the whole sphere of Government planning. Finality also cannot be reached in road matters until further and closer consultation has taken place with the Provinces and until the views of the Post-War Transport Policy Committee have been ascertained. I share the impatience, which no doubt you feel, but it is some comfort to know that planning in the sphere of roads has probably advanced as far and as fast as in any other sphere and that all authorities appear to be unanimous as regards the general priority which the development of communications should have in the scheme of post-war planning.
>
> "The concentration of roads and railways under one Member of Council signifies Government's determination to see that to the maximum possible extent transport facilities are developed in a rational manner. My own approach to the problem is based primarily not on the benefits of a particular scheme to motor vehicle owners or road builders or to the railway budget but on the benefits which a scheme will bring to transport users and to the public generally. In any scheme of transport development the view of the potential user as represented by Provincial Governments and by agricultural and industrial associations and interests must therefore predominate and the function of the Centre must be to pull these views together into a coherent and progressive whole. The final planning of new rail and road transport routes is therefore dependent to a large extent upon the decisions of other governments and departments in regard to the development of the countryside, the opening up of new mineral development and of industrial areas and I trust that the Roads Congress will do all in their power to expedite Provincial and other plans so that at least the initial programmes of road development can be finalised at the earliest possible moment. There is no time to lose if we are to be ready when the day comes to beat our swords into plough-shares and turn our tanks into road rollers.

"Your immediate steps must be directed to the completion of the road plan in its various components. It would, I think, be helpful if with your great experience you would give particular attention to the question of the priority to be given to the various components having regard to your knowledge of the general plans of the Central and Provincial Governments both for the immediate post-war period when men may be plentiful and machinery scarce and for the longer term when financial considerations are likely to predominate to an even greater extent.

"I wish you success in your deliberations and in discharging the great responsibility laid upon you as the leader of the Road Engineers in India and I look forward to the valuable assistance of the Roads Congress during the vital years when India will be marching forward to development in every direction over a rapidly improving road system."

Mr. Vesugar then continued:

You will no doubt share my feeling that this message is not only inspiring but that it constitutes a mandate to us to go ahead and give of our best.

Just about a year ago we met at Gwalior. That was the first meeting of the Congress after an interval of some three years during which engineers had little time to attend conferences. At this meeting there was, as you know, a resurgence of interest in road development which was both surprising and stimulating. Then came the Chief Engineers' Conference at Nagpur which put forward a concrete plan of action. We met again in Bombay in March last to discuss various proposals including the Nagpur plan which we had been able to work upon in the interval.

At that time hopes were high about the progress of the war but we did not quite expect the victorious advance that has taken place in the last two months. The end of fighting in Europe will not, of course, mean the cessation of hostilities in the East but it will certainly bring the end nearer. There is therefore little time to lose in putting the finishing touches to the immediate post-war plan. Demobilisation, or as I would prefer to call it, re-mobilisation, may well be one of the high-lights of the discussions at this session.

Since the question of financing our plans is virtually the last hurdle, and since this must, to a large extent, be the responsibility of the Centre, it would be natural for some of you to inquire at this meeting "What are we going to get?" I suggest to you that the key-note should, on the contrary, be "What are we going to give?" We can thereby perhaps make a definite contribution to the problem of integrating the various responsibilities, both financial and administrative, of the Centre, Provinces, States and local bodies.

If we are to prove adequate to the task ahead and to improve our standard of living to the extent that would enable us to attain a position in the world commensurate with our size and population, the resources from which our plans must take shape will have to be developed with the maximum vision, intelligence and enterprise—and above all courage. Not the least of these resources is the human material which forms the nation and considerable attention should therefore be devoted to its development. The three primary factors essential for this purpose are economic independence, education and ease of communication—all of which are mutually interdependent. In rural India economic independence can only come after a heroic effort extending over a considerable time, and education can only become widespread after systematic universal schooling has been organised. Immediate results can, however, be achieved by the provision of facilities for the free movement of the villager: then he will at once extend his mental as well as his economic horizon.

Whilst everywhere else the world is shrinking, the outlook of the Indian peasant is still limited to that afforded by the use of his own feet or by the bullock cart. In America almost every family has a car and a journey of 500 miles in one's personal conveyance is considered a ordinary undertaking. In India not one peasant in a thousand even has a bicycle. The time will eventually come when India has a firmly established motor vehicle industry, when it is realised that a disproportionate

tax on utility transport is as pernicious as a tax on any other public utility, and when community passenger and goods motor transport will be available to every village. In the meantime, however, it is our duty to give to the cultivator as complete means of mobility as may be possible within the country's immediate resources. Industry can contribute by producing a cheap and satisfactory bicycle so that within a measurable period every family in every village will have its own means of locomotion. But we road engineers must provide the roads; these village roads will necessarily involve a low-cost specification and we shall have to use all our ingenuity to ensure their usability throughout the year.

Engineers are apt to concentrate on the technical aspect of road building and the layman on the convenience and comfort provided by roads. All are agreed on the importance of the road system reaching the village but this agreement rarely finds concrete expression in action. It is opportune therefore that the capital of the United Provinces is the venue for this session. Of all the Provinces and States in India the U.P. has the largest number of villages, almost as many as any other two. It has the biggest village population, the largest land revenue, and the greatest number of working bullocks. In agricultural area it is the second largest, being smaller than Madras only by a small margin.

Whether by weight or value the leading crop of the U.P. is sugar, of which it produces as much as the rest of India put together and four times as much as the nearest provincial rival. The U.P. has the largest railway milage of any province. Yet in spite of these factors only a third of the cane crop is converted to refined sugar and sixty-five per cent of the cane cultivators have to be content with converting their produce to the less remunerative manufacture of *gur*. The reason can be given in three words—*poor rural communications*. An adequate system of village roads, not necessarily expensive, but extensive, and capable of year-round use, would enable the setting up of an alcohol industry capable of comparison with that of any other country.

In emphasising the importance of village roads, I do not wish to underrate in any way the importance of the framework on which these will be built, especially the National Highways and Trails. These have now been more or less defined but before such definitions are finally adopted, the alignments should be given full publicity.

In this matter the public has an obligation and it would be neglecting its civic duty not to have an opinion. Road engineers in the past have had to fight against so much apathy that criticism instead of being irksome is encouraging. But here I would like to make a plea for intelligent and informed comment.

Recently an important commercial organisation criticised the Chief Engineers who met at Nagpur on the grounds that they recommended the placing of an order for 1,200 rollers with foreign concerns. That is a travesty of their resolution, which laid stress on the local manufacture of these machines or as much as was possible. An offer from industry to manufacture and supply the required rollers within a guaranteed period would have been more to the point than the distortion of a carefully considered recommendation.

The Nagpur Conference stressed the importance of cement concrete as *the* (italics theirs) future road material, and went on to recommend that cement production and distribution should be organised on a rational basis to achieve the maximum economy. This is all in the report. Nevertheless criticism has appeared in the press of some recommendations that the Chief Engineers never made. Distorted criticism can only do disservice to the national cause. If the solution to all road construction was concrete, which is not only a permenent but also indigenous material in every country, there would be no asphalt roads for example in Germany or Italy. We must remember that considerable quantities of road tar and bitumen are already made in India and that after the war, in common with other progressive countries, it may be that all imports of petroleum products will be in the shape of crude oil, distillation being carried out on Indian soil.

We have been criticised at times for wanting to build roads only for the motorist. It came as an unpleasant surprise, therefore, to see the village road programme criticised as a possible channel for draining away the little wealth that is to be

found in the villages. If we are to base our activities on such arguments we should logically do nothing. We therefore ask our critics to consult us before they commit themselves to hostile attitudes.

From the professional standpoint two or three matters are of urgent importance. The Government's intention to foster scientific and industrial research was announced by Sir Jeremy Raisman in his last budget speech when he promised a crore of rupees for this purpose. Plans for establishing five central laboratories for Chemical, Physical, Metallurgical, Fuel, and Glass research are already on the way. I am glad to inform you that the Council of Scientific and Industrial Research has also under consideration the question of a Building Research Station and a Road Research Laboratory. The Indian Roads Congress has already done much work on the subject of road research and Government has so far availed itself of the services of this body to guide research activities. We must therefore make the most of this new opportunity to pool knowledge and achieve the utmost from all research.

It goes without saying that the rate of progress achieved in the execution of the road building programme will depend on the engineers at the top. Therefore the necessity cannot be urged too strongly on Provincial Governments of not only grooming their top men for the job ahead, but also of seeing that when the time comes there is a Chief Engineer in each Province exclusively in charge of road development. Road work on a scale not thought of before the war has come to stay and Governments should make their plans now for the expansion of guaranteed and other posts at all levels.

A last point is that with the impending conclusion of hostilities the question of sending our engineers abroad for further training comes into the foreground. Not only has there been a hiatus of several years in the interchange of technical knowledge but with the extensive programme in view, it is important that Indian engineers should have the advantage of knowledge of the latest developments in road science and administration. This is a question to which we may profitably devote attention at this session as here again we must think in terms and numbers very different from those we have been accustomed to in the past.

Again on behalf of the Council of the Indian Roads Congress I wish to thank His Excellency and his Government for their kind invitation to us to meet in Lucknow and for their hospitality. May I now ask Your Excellency to declare this meeting of the Council open and express at the same time the deep gratitude of the Council for the personal interest you have shown and for the encouragement given to us by your presence.

His Excellency in opening the Session said :—

I am extremely glad to welcome the Council of the Indian Roads Congress to the United Provinces and to Lucknow and am grateful also to you for *giving* me this opportunity of attending your opening session. As you, Sir, have indicated, the United Provinces is a large province. I have not checked up the Statements which you have made that the United Provinces have the largest number of villages, the largest rural population, the largest land revenue, the largest number of working bullocks and the largest railway milage. That statement rather took my breath away. I realize, of course, that the United Provinces have an area of a well over 100,000 square miles and a population of over 55 millions. I did not realize that it had the largest land revenue but I would mention that even though it may have the largest land revenue its total revenue from all sources is considerably lower than that of many provinces, certainly lower per head of population than, for example, Bombay. It is also news to me that we have the largest rail milage; perhaps it is because of this that in those black days of 1910 we were called upon to surrender, and did surrender, as part of our war effort, a considerably longer line of railway than any other province. We live in hopes that these railways will be restored quickly after the war, that the Railway Board will treat us kindly and will not turn down our urgent requests for the restoration of these lines with that old and, I would say, out of date argument that these lines are not remunerative.

But we are here to talk about roads, not railways, though I shall say something later about the important question of co-ordinating all means of communications. Looking back to the time when I first came to India, I can see there has been some progress, but the progress has been extremely slow, mainly for financial reasons, about which I shall say something later, and not always very steady. But here in the United Provinces we have, in spite of the war, made some progress during the last five years. For that progress the Roads and Buildings Branch of the Public Works Department deserve the greatest credit and I regard this session of the Roads Congress as a suitable opportunity of expressing my appreciation of their work. The rebellion of August, 1942 showed how defective were the roads in the east of the province; when the railways were destroyed, it became no easy matter to move police and troops to the disaffected areas. Conditions are better now and if we can secure permission to use railway bridges for road transport, the position will be even more satisfactory. We have also extended our roads in the hill tracts of the province and I hope it will not be long before we get a road fairly near to the important Hindu place of pilgrimage, Badrinath, a road which in the possibly distant future will connect up India with Tibet. We have also set ourselves to see that all district head-quarters are linked up and that work has progressed satisfactorily. The Public Works Department in addition to all this new construction have kept the roads under their charge in good order, in spite of difficulties arising from the war, shortage of material and increase of military traffic, and I have frequently heard it said by those who have known this province far longer than I have that they have never seen the roads in such good condition. I have certainly found them in good condition and as I do practically all my touring by road, I must have travelled over many thousands of miles of road. Incidentally I may mention that in 1942 the Public Works Department also undertook. I might say in their stride, the construction of some 30 aerodromes, the concrete run-ways of which, according to the calculations of a mathematical friend of mine, are equivalent to concreting the whole Grand Trunk Road from Cawnpore to Calcutta.

But I must think of the future rather than the past; as I have said in many of my war speeches, three things are necessary for the successful conduct of the war, men, money and material. These three Ms necessary for winning the war are equally necessary for winning the peace, for that development of India which is so essentially necessary if we are to make the country free from want and raise the standard of living. I need not say, and indeed I am not competent to say, much about 'material'. It is for you experts to advise how cement and bitumen and tar can be made available in the quantities in which they will be needed, to say whether anything can be done to improve the ordinary *kachcha* unmetalled road to make it fit for light and slow-going traffic, to say whether the bullock cart can, by the use of pneumatic tyres or by other means, be so improved as to cause less damage to the unfortunate bullock and to the road surface over which it passes. It may be however that we have come to the end of the bullock cart age, which dates back for thousands of years, and are getting to the jeep car age, which may be an advantage. But I am glad to know of the possibility of a Road Research laboratory which will deal with all these problems on the technical side. That clearly must be an all-India institution and the sooner it is started, the better.

Next, as to men—who are to carry out this work? We have not been idle in this province and a departmental committee has examined the problem. They have submitted a very good report, copies of which can be given to any of you who would like to see it. Briefly, the scheme is to expand and develop that very excellent and I might say famous Engineering College at Roorkee. We need Engineers not only for our Roads and Buildings Branch of the Public Works Department but also for the Irrigation and Hydro-electric Branch. I have referred to what you, Sir, have said about the United Provinces being the largest province in India in many respects. Although you, Sir, have not mentioned it—it is hardly relevant to the subject matter of your speech—the United Provinces can I think claim to have the oldest, largest and most efficient irrigation system in the country, a system which we are determined as far as lies in our power to expand. The use of the word 'oldest' may make some people consider that it is out

of date, but our Irrigation Engineers have never been static and are not static now, but are doing all that is possible to harness our great resources of water power.

But again I am straying from the main topic. If we make full use of Roorkee we can get an efficient engineering staff, but I agree that it will be necessary to get engineers trained abroad. It may well be that some of our young soldiers, soldiers who have served in the Sappers and Miners, would profit by this training. It will I think be particularly necessary to have an Engineering Mechanical branch of the Public Works Department to look after all our machines, for in the jeep era we must have some mechanical appliances such as are being used in the war zone and we must have men to look after them, tractors, bulldozers, as well as jeep cars and motor lorries

Then connected with the question of manpower comes the question, what authority will control this development. I said earlier in the speech that there has not been always steady progress. When I made that remark, I was thinking of the deterioration in roads under the control of local bodies. That is noticeable everywhere and I suppose other provinces have the same experience as we have. This deplorable result is due partly to the fact that local bodies have inadequate funds to discharge all their responsibilities; it is also due to other reasons, to the fact that District Boards cannot employ a really competent staff and also to the fact that those responsible for the work of these bodies do not care to see that every rupee spent is a rupee well spent. Are we to have more centralization or more decentralization? My own view is that centralization or rather provincialization is essential. I do not wish to see centralization in the sense that the Central Government should try to run the whole country. The Government of India should co-ordinate work; they should be responsible for National Highways, though the actual work be left to the provincial agency. But they should not interfere in matters of detail; these can be left to the Provincial Governments. They should also be responsible for research and technical advice. But for roads in a province, it will be more economical if these are provincialized. I admit this may raise possibly political considerations. The politicians may be in favour of local self-government; there may be theoretical advantages but my experience has shown that they are outweighed by practical disadvantages. To take a simple example, it is absurd that a District Board should have a good road to the border of the district, that after that, thanks to the inefficiency of the neighbouring Board, there is no road. We must avoid that.

But whether roads are provincialized or not, there must be some authority to co-ordinate all work connected with communications, not merely road communications but communications rail, air, and water. Hitherto these subjects have been separated off into water-tight compartments. Under our present constitution, roads are a provincial subject, while railways are a central subject. Hence we have heard a good deal of rail-road competition; if a successful motor bus service started, the railways become apprehensive that it would affect their traffic returns and reduce their revenue. Questions such as this seem to me to have been looked at too much from the point of view of profit and loss and too little attention was paid to the question whether the scheme would benefit the country as a whole or would develop any backward area. Again, take our waterways. The Ganges is a highway provided by nature for the provinces through which it passes; 100 years ago it was used as a highway and I believe large ships came up as far at least as Allahabad and Cawnpore. But railway competition has killed this river traffic. I do not see why it should not be revived. Admittedly our railways are inadequate for the size of the country and I see no reason why many articles should not be carried by river. Air communication will certainly develop after the war: the rough plans which have been drawn up rather leave this province in the cold; but the province will continue to press its claims with vigour and I hope we shall have air lines from Cawnpore to Bombay and from Cawnpore to Lucknow, Rampur and Delhi. We have after all several large military aerodromes in the province, one of which I see you are visiting, and they should prove most useful for

civil aviation. But these are merely details; the point I wish to emphasize is that there must be an All-India Transport Board to co-ordinate the development of railways, roads, river transport, and air lines, to deal also with the development of our postal and telegraph system and in particular the improvement and extension of the telephone service. I see you are considering a proposal to rename your Congress, the Indian Roads and Transport Congress. That would meet the suggestion that I have made. Another very important point which I suggest your Congress might consider, and again it is a matter which concerns railways as well as roads, is the improvement of suburban communications round our big towns. You are I think visiting Cawnpore; I am ashamed of Cawnpore and so I think are many of the people who live there. But how are we to cleanse this Augean stable? How are we to give the workers in the mills and factories decent houses in which to live, homes in clean and sanitary surroundings, homes which will have nearby a good school and a good playground for their children, good sports grounds for adults and a good dispensary and maternity centre? There is only one way that I can see and that is by developing the suburban area, by keeping the centre of the town for factories. shops and bazars and by putting the factory worker to live outside the town. But you cannot expect the hard-worked artisan to walk three or four miles or more to his work; he must have some cheap means of transport and I hope this Congress will consider this question and advise as experts whether this transport should be by motor bus, by electric trams, electric railways, either above or below ground, or whether, as has happened in London, by a combination of all these methods of locomotion.

I am afraid that I am making an unduly long speech but I am expected, I suppose, to say something about money. I am not a financial expert and I shall start off by quoting the view of financial experts. The financial and business experts who drew up the Plan for the economic development of India, better known as the Bombay Plan, wrote as follows:—

"The estimates of capital expenditure contained in the memorandum are of such colossal dimensions that the whole scheme may appear impracticable to people whose minds are still dominated by orthodox financial concepts. In matters of this kind, the war has been a great educator. Lord Wavell, in a recent speech in London, remarked: 'It has always seemed to me a curious fact that money is forthcoming in any quantity for a war, but that no nation has ever yet produced the money on the same scale to fight the evils of peace—poverty, lack of education, unemployment, ill health'. The answer to this question, which has puzzled many an inquiring mind since the commencement of the war, is that money or finance is not the master of a country's economy but its servant and instrument. The real capital of a country consists of its resources in materials and manpower, and money is simply a means of mobilizing these resources and canalizing them into specific forms of activity. Looking at the problem from this angle, we are convinced that the capital expenditure proposed under our scheme is well within the limits of our resources and that, from a business point of view, such expenditure will constitute a sound and profitable investment for the country."

Again later, they refer to finance as only a 'camp follower' and write as follows:

Finance, only a camp follower.

"It is necessary to emphasize that in a planned economy, we are primarily thinking in terms of commodities and services. Money or finance is therefore completely subservient to the requirements of the economy as a whole and must be treated merely as a means of mobilizing the internal resources of the country in materials and manpower."

With these views I hope you all agree: I certainly do. There may be some who hope that the end of the war will mean a reduction in taxation; that of course is the selfish point of view and there are a good many people in this country—the profiteer and the hoarder are clear examples—who put their own comfort, their own

profit before the well-being of the country as a whole. If we are to carry out our ambitious but essential schemes of post-war development, whether it be road development or the improvement of agriculture and industries, we must have, particularly in the early years, money with which to meet the expenditure, and I do not see how that money can be got except by taxation. We must at the same time push on with those schemes which will increase the wealth of the country, schemes such as those which we have under consideration in this province for the extension of irrigation and hydro-electric power. These schemes will lead to a direct increase in revenue. But we must also not in any way neglect that side of the problem in which this Congress is particularly interested, the development and improvement of roads. Roads of course do not produce any direct revenue unless we go back to that vicious system of tolls, but what has been overlooked in the past is that roads do increase the wealth of the country and thereby increase its taxable capacity. If we are to find the money for raising the standard of living to pay for compulsory education and a widespread system of medical relief, we must raise the national income, we must harness and develop the natural resources of the country. The Soviet Republic in a short period of 12 years, raised the national income fivefold, from 25 billion roubles, but that result was obtained partly because of the extensive and varied natural resources of that country, partly by causing a good deal of human suffering. The Bombay Plan sets a more modest target and I see no reason why that target should not be achieved. If it is not achieved, we shall see little or no progress. But we must make progress and in this all important question of road and transport development the Roads Congress can give, and I know will give, valuable assistance."

Informal discussion

2. The proceedings opened with an informal discussion on the road plan for India. Many members wanted to know what progress had been made at the Centre with the general plan and whether the Government of India had arrived at any decisions on such matters as the constitution of the Road Board recommended in the Nagpur and Road-Rail reports and the extent to which the Government of India was prepared to contribute towards post-war road development throughout the country.

3. Sir Kenneth Mitchell pointed out that "roads" were a provincial responsibility and the initiative in road matters should more correctly be taken by the provinces. Instead of first asking how much the Centre was prepared to contribute towards road development, the provinces should prepare their project estimates (as already asked for), showing what was required, state how much they were in a position to contribute towards carrying out the work proposed in their estimates, and then ask how much the Centre, in its turn, was prepared to contribute.

4. He explained that the Government of India had to consider not only the demands for the development of road communications in eleven provinces but also demands for the development of industries, education, public health, agriculture and other undertakings and services. Until the provinces had given some indication of their requirements it was difficult for the Government of India to draw up its own programme.

5. Many members than referred to the difficulties they were experiencing in drawing up their own plans. The project

estimates, which indicate the immediate needs of the provinces for roads, were all ready or nearly so, but until some sort of lead was given by the Centre, it was difficult for the provinces to complete their plans. The provinces particularly wanted to know whether the Centre would accept financial responsibility for the National Highways.

6. For example, provincial resources were limited and if a province were obliged to rely on its own resources, its plan would have to be correspondingly restricted, the provision for road plant would be limited and arrangements for recruitment and training of staff would have to be scaled down to that necessary to complete the work the provinces could afford to undertake. If, later, the Government of India offered to contribute towards road construction the provincial plan would have to be very fundamentally modified, the priorities changed, the requirements for plant reconsidered, and most important, the plans for training the staff required to carry out the programme would have to be reviewed.

7. Particular stress was laid on this last item because the contemplated extent of the yearly programme of work would govern the extent to which the provinces should arrange for expansion of their technical schools and colleges to train the staff required to carry out the work. Further, the question of training of staff cannot be deferred or trained men will not be available when required to execute the programme.

8. After some further discussion, Sir Kenneth Mitchell undertook to make a statement on the points raised, when the Council assembled again. This statement was subsequently read to the members but is not reproduced in these minutes.

9. After hearing Sir Kenneth Mitchell, the following resolution was passed by the Council.

Resolved that the Government of India should be requested to issue an authoritative statement on post-war road policy and also to expedite the formation of the Road Board at a very early date.

10. The reading of a paper on Road and Road Transport Problems

The President then suggested the Council should follow the example of the Institution of Civil Engineers, London, and ask one or more of its members to read at the next session a paper or papers on road policy and administration with special reference to adjustment of financial obligations and responsibilities between the Centre and the various authorities responsible for roads in India (other than urban roads). The author or authors could study the vast collection of information available with the Congress on matters concerned with road administration and policy, examine as far as possible the system of taxation of road users existing in this and other countries,

and, with the help of members interested in the subject, make definite recommendations which might be of assistance to the Provincial, Central and other administrations in India in arriving at their own road policy.

11. The President went on to explain that the Institution of Civil Engineers, London, had acted as they did because they felt that although the Institution "was not necessarily an authoritative body" on Transport, they should make some contribution towards the solution of post-war transport problems. They made it clear, however, that the Institution was not responsible for the opinions expressed in the paper or in the subsequent discussion on it.

12. After some discussion the Council decided that a paper should be read on the subject and that Mr. McKelvie should be asked to do this with the help of the members. The paper should deal among other matters with the two major problems the solution of which appeared at present to be holding up progress on the road plan, namely, the constitution, functions, and powers of the proposed Road Board, the methods to be adopted to finance the road plan, including the extent to which transport policy would affect the solution of two problems.

13. It was realized that the Provinces and States had been asked to agree to a Road Board but that it had not been fully explained what it was that this Board would do, what powers it should exercise, and what safeguards should be imposed on its operations so that it would not and could not infringe Provincial and State sovereignty in the matter of road and road transport administration and control.

14. Similarly the Provinces and States had been asked their opinion on a number of proposals such as the creation of a Central Transport Budget, control of goods traffic on National Highways, the nomination by the Centre (with the concurrence of the Provincial Governments) of a whole-time Provincial Transport Commissioner, Central control of National Highways and such matters without, for example, being told definitely what items would or would not be included in the Central Transport Budget, what Central control of National Highways would imply, etc., etc.

15. It was agreed that the Council should request the Government of India to permit Mr. McKelvie to make his suggestions to the Council, not as a representative of Government but in his individual capacity making use in his report of all facts and figures which are not confidential.

16. Confirmation of the minutes of the Twentieth Meeting.

These were taken as read and confirmed, except that Mr. Adke wished to place on record his objection to the Council endorsing paragraphs 86 to 88 of the Nagpur report (item 8 (v) of the minutes of the Twentieth Meeting of the Council).†

† See pages 56, 57 *Ibid.*

17. Approval of the Report of the Executive Committee.

The report of the Executive Committee, as recorded in the minutes of the two meetings held by it since the Council met in Bombay, was read and confirmed.

18. Proposal that the Indian Roads Congress should associate itself more closely with Road Transport.

The following alternative proposals had been placed before the Council in a note written by Sir Kenneth Mitchell —

(a) To rename the Indian Roads Congress as the Indian Roads and Transport Congress, or

(b) To ask the Institute of Transport, London, to open a branch in India to be affiliated with the I.R.C.

These were considered along with the report of the sub-committee appointed by the Council at its Bombay meeting. (Item 13 (ii) p.12 of the minutes of the 20th meeting†).

19. Sir Kenneth Mitchell placed on the table two copies of the Journal of the Institute of Transport, London, and said that he had already approached the Institute regarding the possibility of their forming a branch or centre in India. Pending their reply, he suggested the Council might express its views on the general question.

20. Mr. Chinoy, the convener of the sub-committee appointed at the last session, explained what his committee had done and suggested that, with the idea of associating Transport interests more closely with the Congress, a transport association should be formed and the Congress should so alter its rules as to permit the association to join the Congress as a corporate member, nominating representatives on the Council.

21. After some discussion it was decided that it would be inadvisable to change the name of the Congress to the Indian Roads and Transport Congress or in any way to admit transport members as such since by doing so, there would be danger of the Congress dissipating its efforts and neglecting the main purpose for which it had been formed. At the same time it was agreed that the Congress should be associated as closely as possible with Road Transport interest.

22. The Council endorsed Sir Kenneth Mitchell's proposal that the Institute of Transport should be asked to open a branch in India.

Mr. Ormerod proposed that the Roads Congress should recommend to the Government the formation of a Roads Transport Congress on parallel lines to the existing Indian Roads Congress. The Council agreed that there is a great need for an association of such a standing that it could give authoritative opinions on all

† See page 60 *Ibid.*

Road Transport matters and accordingly accepted Mr. Ormerod's proposal. When the new Transport Congress is formed, the Council will consider how best the two bodies could be affiliated so that road makers and road users can be of mutual help and assistance to each other.

23. Changes in the Memorandum, Rules, and Regulations of the Indian Roads Congress.

The provisional reprint of the Memorandum, Rules and Regulations having been circulated to members, with due notice as required by the rules, was approved subject to the following modification :—

Rule 7 on page 3 of the Reprint to read as under :—

7. **Subscription :—**

(i) A yearly subscription shall be payable by members on the following scale :—

		Rs.
Patron, Vice-patrons, and Honorary members	..	Nil
Ordinary members	..	20
Associate members	..	120

provided that a rebate of Rs. 5/- in case of ordinary members, and Rs. 20/- in the case of associate members may be claimed if the subscriptions are paid within three months of the due date;

and provided that the subscription payable by any member who shows to the satisfaction of the Council that his total emoluments on the date his subscription becomes due are not more than Rs. 400/- per mensem, the yearly subscription shall be reduced to Rs 12/- and the rebate to Rs. 2/-.

(ii) Ordinary and associate members who leave India on retirement are allowed to compound their annual subscription for a sum of Rs. 25/- for so long as they reside outside India, Burma and Ceylon.

(iii) Ordinary members whose subscriptions are not in arrears may compound their future annual subscription by a single payment depending upon their age at the time in accordance with the actuarial age table below.

Associate members of 55 years and over may, on their retirement from their profession, become ordinary members and compound for life by a single payment, according to same table.

Actuarial Age Table for Compounding for Life Membership.

Compounding		Compounding		Compounding	
Age	Fee	Age	Fee	Age	Fee
25	298	36	230	47	135
26	293	37	222	48	125
27	287	38	215	49	115
28	282	39	207	50	104
29	276	40	198	51	93
30	270	41	190	52	82
31	264	42	182	53	70
32	257	43	173	54	58
33	251	44	164	55	45
34	244	45	155	56	30
35	237	46	145	and over	

(iv) A year shall, for the purposes of this Rule, be from the first day of October until the last day of September following. Subscription shall be due on election and on the first day of October of every year following that date while a person continues to be a member of the Society. Provided that if a person is elected as a member of the Society after the 31st March in any year, he shall only pay half subscription for that year.

24. Some members suggested that there were still a few defects in the Memorandum of Association, Rules, Regulations, and Bye-laws as printed. Consideration of proposed amendments will be taken up at the next meeting provided 30 days' notice is given and the conditions laid down in rule 25 of the Memorandum of the Association are complied with.

25. **Vacancies on the Council**

The Secretary reported that there were two vacancies on the Council and these should be filled as provided in item 13 (a) of the Memorandum of Association. It was decided to leave it to the President to nominate members to fill these vacancies. Three names were suggested for his consideration but he was left free to fill the vacancies at his discretion.

26. **Discussion on the Memorandum issued by the Council as provided under item 12 (ii), of the minutes of the last meeting.†**

Members discussed the reaction of road administrations and the public to the Nagpur and Road-Rail reports. It was agreed that these reports had generally been favourably received and that no further action was required at present by the Council.

† See page 60 *Ibid.*

27. **Budget estimate for 1944-45 and revised Budget for 1943-44.**

Budget proposals for 1944-45, having been circulated to the members in advance as required by the rules, were approved by the Council subject to the following modifications :—

(a) To provide on the revenue side under item (II) (v) "Glossary Rs. 500/-."

(b) On the expenditure side, under *Item XIII (iii)* Column (3), to raise the amount of Rs. 200/- provided for experiments with wooden cart wheels to Rs. 500/-.

28. It was suggested that in view of the large volume of work that is being done by the Indian Roads Congress for the military authorities in the design of the bridges to cater for heavy military loadings the E.-in-C.'s Branch be approached for a donation in order to place the Indian Roads Congress on a firmer footing.

29. It was suggested that separate notices advertising the publications that are on sale with the I.R.C. should be circulated to Council members so that they could use their good offices to secure greater publicity and sale.

The revised budget for 1943-44 was then adopted by the Council.

30. **Reports of the Sub-committees:—**

The reports of the various sub-committees were considered:—

(a) **Bullock Cart Sub-committee.**

The report of the Sub-committee prepared by the convener, Mr. Murrell, was recorded by the Council. It was explained that improved designs for the bullock cart are under consideration and that a fuller report would be made to the Congress when it meets in January 1945. It is understood that Bengal, Bihar, Bombay, Assam, Madras, U.P., the Punjab, N.W.F.P. and the States of Bhavanagar and Gwalior might be willing each to finance the manufacture of one or two pairs of improved wheels constructed to designs prepared by the Sub-committee, and to have these tested under ordinary working conditions on roads.

A suggestion was made that as tests on roads would take a considerable time, accelerated tests should be arranged on the Test Track at Alipore, Calcutta. Mr. Chambers said that this would be possible and such tests could be advantageously combined with tests on stabilised road surfaces. The matter was left by the Council to the Technical Sub-committee for decision.

Regarding the use of materials available from the Disposal Board for constructing improved types of bullock carts, it was suggested that the Provincial Governments should make preliminary enquiries as to the feasibility of manufacturing these carts on a commercial scale and then address the Disposal Board of the Supply Department to help them with necessary parts.

The Council expressed its grateful appreciation of the help rendered to this Sub-committee by Messrs. Burma Shell and particularly by Mr. Vagh in preparing experimental wheel and financing their manufacture.

(b) Soil Stabilization Sub-committee.

The report of the sub-committee was adopted. Mr. Freak, for the convener, explained that experimental work in the Punjab would be started after the rains. Mr. Mehra's suggestion that accelerated tests on soil stabilized tracks should be undertaken on the Test Track at Alipore was referred to the Technical Sub-committee.

(c) Education Sub-committee.

The interim report of the Sub-committee was adopted. Mr. Kynnersley described the work done so far by the Sub-committee, and the various proposals under consideration.

The Council elected Mr. Dean as a member of the Sub-committee in place of Mr. Anwarulla.

The suggestion of Mr. Vesugar that Provincial Govts. should be requested to agree to transfer engineering officers from one Province to another on deputation for a period of years was endorsed by the Council. It was further decided that this scheme should generally be confined to Assistant, District, and Executive Engineers and all transfers should be on the advice of the Road Board.

The Council also recommended that deputation allowances should be payble to these men and all such allowances, transfer costs, etc., should be met from the Reserve in the Road Fund.

(d) Bridges Sub-committee.

Mr. McKelvie, the convener of the Sub-committee on the revision of bridge specifications, explained to the Council the work so far done by the Committee. Mr. Lawley considered that very little attention is being paid to the design of bridge abutments and that the Committee should examine this question with particular reference to the increased earth thrust induced on abutments by heavy vehicles such as tanks. Mr. Nivas enumerated several

cases of bridge failure due to faulty designs of abutments. Mr. Nivas was asked by the Council to write a paper for the next Congress on the failures of bridges and the remedial measures he would recommend.

It was suggested that the Indian Roads Congress should associate itself more closely with the Central Board of Irrigation, where considerable research work has been done on river training, flood discharges, etc. The Council was informed that this is already being done.

Mr. Nivas was co-opted as a member of the Sub-committee in place of Mr. Cochrane who had resigned.

The report of the Sub-committee was adopted.

(e) Sir Kenneth Mitchell Fund Sub-committee.

The report of the Sub-committee was adopted. The Council expressed its appreciation of the trouble taken by Mr. Dean, in getting the designs made and the dies cut for the medal at the Royal Mint, London, while he was on short leave.

(f) Waterbound-Macadam Sub-committee.

Mr. McKelvie explained that the work of the Sub-committee was not sufficiently advanced to warrant a report and that a detailed report would be placed before the Council at its next meeting.

(g) Technical Sub-committee.

The report of the Sub-committee was adopted.

It was suggested that a small Sub-committee should be formed to examine the literature on the subject of the increase in the adhesive capacity of binders that could be made possible by adding water, certain oils such as turkey red oil, and certain minerals, such as lime, etc., to the aggregates. Several provinces have been carrying out tests, which were described by the members responsible. It was decided that an attempt should be made to have the results correlated. Members who have specialised in this subject agreed to assist in this matter.

(h) Transport Sub-committee.

Already discussed *vide* paragraphs 18 to 22 of these minutes.†

31. Ways and means of expediting land acquisition and the policy to be adopted.

The Council was informed that this subject was under consideration by the Govt of India and that a draft note was being prepared by the Consulting Engineer preparatory to

† See pages 83, 84 *Ibid.*

the setting up of the small legal committee to advise on the subject as recommended by the Nagpur Conference.

32. **Employment of demobilized men.**

(i) Sir Kenneth Mitchell in opening the discussion said that the Chief Engineers of Provinces and States should now begin to consider how they would employ demobilized men. They might, in those provinces for example where large scale quarry operations would be required, begin at once to devise methods for working the quarries and transporting materials from them. Demobilized men and motor transport released from the Army could probably be utilized on a large scale on this type of work. Chief Engineers should also now make up their minds whether demobilized men should be employed individually or in military units. It had been stated that the Road Plan could provide work for 6,000 lorries, but this might be an under-estimate.

(ii) Brigadier Obbard said that the question of employing demobilized men was now being examined by the Resettlement Directorate in consultation with E-in-C.'s Branch and that he would request Directorate to get into touch with the Consulting Engineer (Roads). He requested those responsible for the Road Plan to consider how far and on what lines employment of demobilized soldier could be entertained, the preferential terms necessary, and the ways and means of meeting the extra cost which would be involved.

(iii) It was generally agreed that the best method of employing demobilized personnel would be in units, on piece work or contract work, the value of the work at civil labour rate being charged to the civil estimates and the balance to the defence or demobilization estimates. Further, the general opinion was that these units should be employed on definite works, separate and distinct from those on which contract labour was employed. It was suggested that the demobilization authorities should train some units to handle modern road plant and machinery etc. It was estimated that road work valued at one crore of rupees would ordinarily employ for one year (300 days), unskilled labour at contract rates varying in numbers from 12,000 to 18,000 depending on the type of work and local conditions. It was agreed on all sides that demobilized labour would be very much more expensive than contract labour and the Council reiterated its opinion that the extra cost of employing this labour, if only for the sake of proper accounting, should be debited to the defence or demobilization estimates and not to the civil estimates.

(iv) The Council decided that this question should be taken up for further consideration at the next meeting, when Chief Engineers would describe the plans of each province for utilizing the services of these men.

33. Collection of road statistics

The Council decided that arrangements should be made to collect the following statistics from Chief Engineers of Provinces *and States* :—

1. Milage of roads under various classifications such as concrete, tarmac, grouted, painted, metalled with limestone, trap, etc.
2. Ruling crust width, bank width.
3. Average life and cost of maintenance with average traffic intensities.
4. Average cost of construction.
5. Details of stretches of roads badly damaged by bullock carts and other traffic, and requiring improved type of surface. The suggestions made in paragraphs 52 and 53 of paper *J. 1913.* "Proposals for an All India Bullock Cart Survey" were also approved, and it was decided to request Chief Engineers to put into practice these suggestions in all Provinces, to the extent possible.

The detailed questionnaire suggested in Mr. Vesugar's paper on "Proposals for an All India Bullock Cart Survey" was approved. (See proceedings of the I.R.C., Vol. VIII, pages 198 to 202).

34. Venue of the next General Session of the Congress*.

It was understood that the Madras Govt. who had earlier invited the Congress to hold its next session (Jany. 1945) in the Presidency are not now in a position to act as hosts. The President suggested that if accommodation could be secured at Delhi, the session might advantageously be held there. An alternative place would be Aurangabad where there is sufficient hotel accommodation. The possibilities will be explored.

35. Road Research Laboratory.

(i) The President explained that the Industrial Research Planning Committee of the Govt. of India have under consideration a proposal to expand their present organization in India and to *include in it among other research schemes, a Building Research* Institute and a Roads Research Institute.

(ii) It was decided that a sub-committee should be appointed to examine the proposal and make recommendations. Sir Kenneth Mitchell, Brigadier Obbard, Messrs. Shannon, Vesugar, McKelvie, Kynnersley, Dean, Chowdhary, Fielder, and Raghavachary were appointed to the Committee.

(iii) It was suggested that the Buildings and Roads Research Institutes should be located at the same place, preferably Delhi, and that the Roads Research Institution set up by the Indian Roads Congress (the Alipore Test Track) should be affiliated with the main Roads Research Institute when it was formed.

* Madras has since confirmed their invitation to the Indian Roads Congress to hold the next session at Madras.

36. **Provincialization of District Board Engineering Service.**

(i) The Council at its Bombay meeting asked the Executive Committee to examine, in consultation with members, the question of provincializing District Board Engineering staff and make recommendations. Mr. T. Lokanathan submitted to the Executive Committee a report on the evolution of the District Board Engineering service in Madras where the District Board Engineers and Assistant Engineers are now in a provincial cadre with a separate Chief Engineer and 3 Superintending Engineers for communications. A note on the Road Administration in Madras and suggestions for adoption of a modification of the Madras system in other provinces was prepared by the Secretary and placed on the table for consideration of the Council.

(ii) R. S. Fateh Chand while agreeing that the Madras system had produced very satisfactory results was in favour of reverting to the old system which existed before the Decentralization Committee reported in 1917 as this system was even more satisfactory and efficient than the Madras system. He explained in detail the need and urgency for early action in this matter of provincializing District Board staff.

(iii) There was not sufficient time to examine the alternative proposals in detail. Mr. Fateh Chand had produced a great deal of statistical and other information and had indicated from reports of various committees appointed by the legislature of his province that public opinion was generally in favour of the change he advocated. It was decided that the details should be considered by the Executive Committee and the matter further debated at the next meeting. In the meantime, the Council wished to place on record its agreement with the general provincialization proposal.

(iv) It was understood that most of the Provinces are agreeable to the provincialization of District Board Engineering services and the taking over of roads from the Boards.

(v) The following resolution moved by R. S. Fateh Chand and seconded by Mr. Adke was passed:

> **"The Council recommends that the Government of India be requested to suggest to Provinces that they should provincialize the Engineering staff of the District Boards at once and bring them into a common cadre."**

(vi) In the meantime it was suggested that in view of the fact that in most provinces the engineering staff in the provincial cadres were not sufficient to undertake the war work and inescapable civil work which the provinces had been asked to complete, and since it had been stated District Board Engineering staff in many areas were not fully employed, Chief Engineers of Provinces should take action under their existing rules, in the general interests of the country, to

employ District Board Engineering staff more fully on war work. This could, in some cases, be done by doubling up some of the existing District Board charges and employing the released men, engineers, overseers, accountants and clerks, directly under the Chief Engineer. Chief Engineers were requested to explore more vigorously than in the past the possibility of making fuller utilization of the engineering resources of their provinces.

37. The Council expressed its desire that the President should convey the thanks of the Council to the U. P. Government for permitting the session to be held at Lucknow; to H. E. the Governor for opening the session and for his encouraging address; to Messrs. Walker, Mahabir Prasad, Jagadish Prasad, Bhatnagar, Swami, and other U.P. P.W.D. officers and staff for the arrangements they made for accommodation and tours of inspection, and other help; to Sir Padampat Singhania for giving the delegates lunch on the 15th September 1944; and to the authorities of the Chakeri Aerodrome, and T. P. I. Factory at Cawnpore for showing the delegates round their works and for the instructive explanations given on the various engineering processes. Mr. Walker was particularly thanked for his very active share and help in all the arrangements.

APPENDIX B

Meeting of the Council of the Indian Roads Congress, Lucknow 1944. Programme of visits—September 15, 1944.

The Indian Roads Congress visited in 1937 the experiments carried out on the Lucknow-Jhansi Road, the details of which appear on pages 240 to 248 of the Proceedings of the Indian Roads Congress, Volume III. Further notes on these experiments are as follows.

The following symbols have been used, the denominator indicating the year of treatment:

TRA—Trinidad Refined Asphalt.

Sx—Spramex.

Pm—Premix Macadam.

BB—Brick Ballast.

T.2—Road Tar No. 2.

NOTES ON LUCKNOW-JHANSI ROAD

Stop I

Mile 1.

Stone/25 TRA/26 TRA/29 Sx/35 Sx/40

The surface had become very uneven on the east side. To improve the surface, the method of drag brooming recommended in Roads Congress Paper 1-40 by Mr. W.L. Murrell, O.B.E., B C.E., A.M.I C.E., was tried in April 1944 in a 9 ft. strip from Furlong 2, to Furlong 6. The grit was screened in 2 grades and precoated with heated tar. The surface to be treated was given a thin coat of paint and the large size precoated grit lightly spread on the surface and the drag spreader run over it so that the grit collected into the depression and was removed from the ridges. Finer precoated grit was similarly spread over the surface and the drag spreader run over as before. The surface was then sanded with Badosa sand and rolled with a light roller. The tar was allowed to harden for 4 days before allowing traffic over the treated surface.

The cost worked out to Rs. 4/3/- per 100 Sq. ft. The surface has improved appreciably.

Mile 2. Traffic 2000 Tons.

Stone/25 TRA Pm/26 Sx/30/32 Sx/35-36 SA/39

Owing to the concentration of heavy bullock cart traffic on the sides, the surface became very uneven and 10 ft. strips of 1: 2: 4: C.C. 4" and 6" thick were laid after digging out the premix in 1929. Due to poor drainage and heavy concentration of traffic some of the slabs cracked badly and the wear has been fairly rapid. The surface of the C.C. haunches is uneven but they are still standing.

One of these bays was dug out in 1941 and relaid with fresh

cement and sand but with the old concrete as ballast. This slab is standing fairly well and shows that old concrete can be used as ballast *where it is very expensive.*

Mile 3. Traffic 4000 Tons.

Stone/25 TRA Pm/27 Cubex Tar/31 Sx/36 Sx/39

As in the case of mile 2 the surface became very uneven on the edges due to heavy bullock cart traffic and in 1930 the asphaltic concrete was removed from one side and C.C. 6" thick and 9 ft. wide was laid for the heavy incoming traffic from the goodshed. The slabs have worn and cracked due to heavy concentration of traffic and bad drainage but are still standing.

Mile 5. Traffic 2000 Tons.

The experimental length of shell-crete mentioned in the note given in the proceedings of the Congress 1937 was replaced with 5½": 3½": 5½": concrete 16ft. wide.

Mile 6. Traffic 1500 width 16ft.

Furlongs 1-4 C.C. 3½": 2½": 3½": 1938.

Furlongs 5-8 3½": uniform. 1938.

Both sections are still standing.

Stop II.

Mile 9. (Furlong 1-4) Traffic 800 Tons.

Brick ballast/36; Colas/June 1936; Sx/Oct. 1936; Sx/May 1941.

The mile is standing well.

Mile 24.

The following experiments were tried in April 1939.

Fur. 1:—½" Shell Spra, 7.2 cft. per 100 cft. precoated and sealed.

„ 2:—1" Shell Spra, 10.2 cft. per 100 cft. precoated and sealed.

„ 3:—1" Shell Spra on priming coat — 7.8 cft. per 100 sft. precoated and sealed.

„ 4:— 2 coats of shell spra 3.84 ft. per 100 sft.

„ 5 to 8:—Socony Asphalt @ 40 lbs. per 100 Sq. ft., Bharatkup grit 2.12 Cu. ft., sand, 1.5 Cu. ft. followed a month after with Socony Asphalt 27 lbs., grit 2 cft.; and sand 0·8 cft. per 100 Sq. ft.

All standing well.

Mile 25.

Furlong 1 to 4 1 inch Proctor. Premix — April 1939.

Furlong 5 to 8 -do- -do- June 1937.

Stop III.

Mile 29. Traffic 700 Tons

B.B./36; T2/Nov. 1936; Sx/June 1938; Sx/May 1940.

All paint scraped and repainted in May 1944.

The mile began to flake badly in 1942 and the failure has been attributed to various factors :—(1) Salt in bricks and soil. (2) Failure of bricks sub-grade. (3) Disintegration of the first coat of Tar. (4) Excess of bullock cart traffic.

Miles 32, 33 and 34.

Have been treated similarly. The failure of these miles under about the same traffic as mile 9 which has been standing satisfactorily is worth noting.

Stop IV.

Mile 36.

The experimental slabs mentioned in the 1937 report of Congress did not behave well. Within 3 years of their being laid the slabs cracked and developed patches. 1 inch "GUNITE" laid over the broken slabs did not adhere satisfactorily to the old concrete and failed under traffic. All these experimental slabs were taken up and replaced with 1:2:4 cement concrete 16′ wide in March 1939; (Furlong 1) 4″—2″—4″ in 1939. (Furlong 2) 4″—2″—6″ with ¼″ bars one foot apart; in 1939. Furlong 3-4 6″—4″—6″ unreinforced in 1939; Furlong 5-8 6″—4″—6″ unreinforced in 1938.

All standing well

Mile 37.

In this mile there are two test lengths of Tar/Kankar premix and Tar/stone premix, laid under the direct control of the Shalimar Tar Co. in 1935-36. The Tar/Kankar premix was purely experimental and was not guaranteed by the company. The traffic in this section amounts to over 1,000 tons per 24 hours.

Furlong 7—Stone premix carpet coat with Tar No. 3 at 2.5 lbs. per cu. ft. uneven.

Furlong 8—Kanker premix with Tar No. 3 at 5 lbs. cu. ft. This is more uneven.

The greater unevenness in furlong 8, appears to be due to the larger quantity of binder used.

Mile 38. (Furlong 1 to 4)

The road was Trinidad Refined Asphalt grout laid in 1928 over water bound stone done in 1927. The thickness of the grouted coat was 3 inches. The traffic is not more than 1000 to 1100 tons per 24 hours. The mile did not stand well; ruts appeared first and then the whole surface became uneven. The Asphalt Carpet was replaced in August 1937 with 6″—4″—6″C.C. slab which is standing satisfactorily.

Mile 40.

This mile was constructed in 1929 and was one of the first

miles laid by the staff of the Lucknow Division. The mile is of interest as showing the marked degree of waviness causing uncomfortable travelling, which can result from lack of care and knowledge in laying the concrete. It is believed that this waviness is chiefly due to lack of attention in bedding the side forms firmly, seeing that they are correctly levelled and ensuring that the concrete on either side of joints is perfectly true to level. The general design etc. of the concrete was the same as in the miles already seen.

Mile 45.

Cement concrete 9 inches: 6 inches : 9 inches in section was laid in 1931. Prior to this the road was kankar which used to last not more than a year. The traffic amounts to about 2000 tons per 24 hours and consists largely of bullock carts. The concrete pavement is 20 ft. wide without any central joint. An insulation layer of sand was provided under the concrete and the surface of the latter was treated with silicate of soda on completion. Except for occasional filling of the joints with Bitumen there has been practically no expenditure on maintenance. The mile is an example of a fairly old length of a thick concrete slab which is behaving normally.

Mile 45 BRIDGE IN FURLONG 8.

At this point the concrete slab is of interest because the roadway over the bridge was laid in one continuous slab 109 feet long and $18\frac{1}{2}$ ft. wide, and 6 inches thick throughout. The edges were not thickened. The slab has cracked in the centre.

GRAND TRUNK ROAD

Mile 620 to 623.

There is no change in the surface of these miles since the Roads Congress last saw them in 1937 *vide* proceedings of the Indian Roads Congress, Vol. III, page 238-239.

Mile 624.

Originally this mile had a T.R.A. semigrout surface in fur. 1 to 4 and T.R.A. full grout surface in fur. 5 to 8, laid in 1929. These surfaces did not stand a traffic of 1650 tons in this mile and had ultimately to be replaced with cement concrete in May, 1937.

A slab 3"—2"—3" reinforced with $\frac{1}{8}$" bars 6" mesh was laid in furlong 1 to 4 and a slab $3\frac{1}{2}$"—$2\frac{1}{2}$"—$3\frac{1}{2}$" was laid in furlong 5 to 8. The proportion of concrete was 1: 2: 4.

JOURNAL OF
THE INDIAN ROADS CONGRESS

No. 4—NINTH SESSION

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NINTH SESSION—MADRAS—FEBRUARY 1945

CALCULATION OF THE STRUCTURE OF ROADS.

(PAPER No. IX—98)*

DISCUSSION.

Monday, February 12, 1945.

Mr. G.M. McKelvie (Chairman) introduced the Paper for discussion in the unavoidable absence of the Author, Brigadier Lang Anderson.

Mr. K.S. Raghvachary congratulated the Author on contributing a Paper on the design of wearing surfaces and sub-grades of roads at such an opportune moment as this. The need for standards of design was felt by the Chief Engineers at the Nagpur Conference and they asked the Indian Roads Congress to appoint Technical Sub-committees to draw up standards and specifications for types of roads to suit the existing and anticipated traffic requirement in the next 20 years. A discussion on the Paper now before Members and the Paper itself would, therefore, be a great help to these Technical Sub-committees when they came to fix road standards.

Continuing Mr. Raghvachary observed that as the design of wearing surfaces and sub-grades on a scientific basis had been dealt with in several standard treatises and empirical formulae were already available, he would confine himself to a few observations on the differences between the Author's theory and that generally advocated. He doubted the observation of the Author that brick on edge pavement would reduce the spread and would have less strength against crushing than when laid flat. The experience of many engineers would indicate that the reverse is the case. Mr. Raghvachary cited the experimental work done in the Delhi-Meerut road near Delhi where brick trackways were laid in 1941 on edge, in herring-bone, diagonal and straight bonds, on natural soil compacted at optimum moisture content by sheepsfoot rammers and rollers. The traffic was over 1,600 tons per day. These brick trackways had behaved wonderfully well for over three years without any appreciable maintenance and were only removed and the road restored to the original specification as the purpose for which these experiments were conducted had been successfully served. These trackways

*Published on pages 1 to 6 of Part 1, Vol. IX of I.R.C. Proceedings.

had been inspected by the Members of the Indian Roads Congress Council in January 1941. Several hundred miles of road had also been constructed to this specification in Baluchistan and are reported to be standing well.

He also felt doubtful about the use of a premix of $1\frac{1}{4}$ inch thickness which in summer would be cut by the narrow steel tyre of the bullock cart wheel.

Regarding the statement of the Author that the distribution of pressure of wheel loads would be downwards through the body of the road, diverging at an angle of 45° from the vertical, Mr. Raghvachary remarked that the intensity of pressure along the vertical axis of the load at any depth from the surface would, in the case of all but nearly rigid pavements, be much more than the average as calculated from the principle of conical dispersion and that due allowance should be made for this in the design.

He questioned the classification of the *materials* of road construction as *rigid, plastic*, or *loose*, as rigid materials like granite and other road metal could provide, with a bituminous binder, a plastic pavement while the same material could form the coarse aggregate of a rigid pavement such as cement concrete. He considered that this classification should be confined to different types of road surfaces.

He felt that the greatest need at present is to design on a scientific basis the thickness of the soling and wearing coats for *water-bound macadam roads*, as it is in this type of road that arbitrary and 'rule of thumb' methods are largely used, in spite of the fact that the major portion of the annual road expenditure of over Rs. 6 crores is being spent on roads of this type. The macadam design is based on the principle of utilizing the sub-grade support at all points, while rigid pavement design (concrete pavements), depends on bridging over small spans by slab or beam action. The macadam design therefore should depend on :—

(a) the safe bearing pressure of the soil supporting the road crust,

(b) the wheel loads using the road, their nature and intensity, and

(c) impact.

Soils have a wide range in supporting power and this varies greatly at different times even in the same soil, depending on the moisture content and the degree of compaction at the time.

Pavement designs have, therefore, to be based on the safe minimum supporting power of the soil under varying climatic conditions all the year round. Soils have been classified in the U.S.A. in 8 broad groups with minor sub-divisions on the basis of their bearing power (the Californian Bearing Ratio) and their plasticity index.

The thickness of soling coat where necessary and of the wearing surface is now determined in a scientific manner in the U.S.A. and other countries with reference to this classification. When the Central Soil Research Institute is set up in this country, it will be possible to carry out tests on the bearing capacity of different Indian soils under varying conditions and evolve a similar classification.

He observed that in the case of waterbound macadam roads, the design should take into account :—

(i) the degree of inter-locking of the aggregates in the wearing coat and sub-grade,

(ii) wheel loads that would be using the road, and

(iii) contingency of the wheel loads acting at edges of the pavement.

No consideration had been given by the Author to impact which is a factor depending on the degree of unevenness of the surface. Mr. Raghvachary considered that for purpose of design it would be sufficient to provide for an impact due to a fall of the wheel load of say ½ inch to ¾ inch.

Mr. Brij Mohan Lal referred to a previous Paper "Safe Wheel Loads for Indian Roads" by Messrs. Mitchell and Jagdish Prasad, read before the Congress in January 1938 at Hyderabad. The main difference between the present and the previous Paper was with regard to the safe load allowed on ordinary alluvial earth, which was in the first Paper assumed as 0.75 ton per sq. ft. or 12 lbs. per square inch. Brigadier Lang Anderson had, however, allowed a pressure of 2 tons per square feet or 31 lbs. per square inch, as in the Author's opinion the pressure would be intermittent and not constant as in the case of foundations of buildings.

Though some allowance would appear permissible on this account, Mr. Brij Mohan considered that the figure of 2 tons per sq. ft. was much on the high side. He would, however, accept a pressure of 1 ton per sq. ft. as safe, especially when roads were surfaced with tar and bitumen and thus made waterproof. With a permissible load of 0.75 ton per sq. ft., Messrs. Mitchell and Jagdish Prasad

showed in their Paper that a thickness of 13 inches or 15 inches road crust would be required to take 3-ton loads if 50 per cent or 100 per cent of impact were allowed respectively, and that for the 1-ton wheel loads of bullock-carts a thickness of 9 inches of road crust would be necessary.

Continuing Mr. Brij Mohan Lal observed that in actual practice, roads in the Punjab have been and are being constructed on a consolidated thickness of 7½ inches, consisting of 4½ inch brick or stone soling coat and 3 inches consolidated wearing coat. These roads have been carrying heavy motor transport without any detriment to the road surface, thus justifying the adoption of a higher load than 0.75 ton per sq. ft.

He stressed the importance of improving the bearing capacity of soils by stabilising the soil and compacting it before laying a hard crust, as expenditure on such improvement would be more than offset by the saving effected by using a thinner road crust.

He also questioned the opinion of the Author regarding the conical dispersion of load at an angle of 45° throughthe brick soling coat as, in his opinion, each brick would act as an independent medium spreading the load only to the soil exactly below it unless the bricks were bonded by mortar at least as strong as themselves.

The Author's objection to brick on edge soling would, he considered, be against the general practice in the Punjab where the usual specification for soling coat was brick on edge. He did not also agree with the Author that brick on edge would have less strength against crushing than when laid flat, as the moment of resistance for a brick laid to a thickness of 4½ inches is much greater than that of a brick laid flat to a thickness of 3 inches. He felt that these points would vitally affect the design of road structures and he suggested that the Technical Sub-Committee should take the matter in hand and issue a technical memorandum on the subject after necessary research and experiments.

Finally, he felt that instead of adopting a wearing coat of 1 inch tar-stone premix carpet for a Class 12 load as advocated by the Author, it would be possible to have at the same cost a 4½ inch loose or 3 inch consolidated waterbound macadam with a surfaced wearing coat which would disperse the load on a greater area of the sub-grade. The pressure on the bricks would then be distributed over (5″ + 6″) by (6″ + 6″) or 132 sq. in. With bricks laid flat, this rectangle of 11″ × 12″ would spread over six bricks, that is an area

of about 250 sq. inches, giving a bearing pressure of 2 tons per sq. ft., safe according to the Author's assumption of safe load on soils. It would NOT, therefore, be necessary to provide another layer of bricks as suggested by the Author.

Mr. A.W.H. Dean said that applying Brigadier Lang Anderson's formula for the thickness of the road crust to aerodrome construction, it would be seen that for an aeroplane wheel load of 7 tons per sq. ft. applied on an ellipse of 6 sq. ft. in area (or 42 tons total), a thickness of $14\frac{1}{2}$ in. of brick soling would be required as worked out below.

If h is the thickness of the crust, and limiting the safe intensity of pressure at bottom to 31 lbs. per sq. in., we have by applying formula (ii) on page 3 of the Paper

$$31 = \frac{42 \times 2240}{3.1417\,(h + 16.5)^2} \quad \text{or } h = 14.5 \text{ in.}$$

This also roughly agrees with airfield construction experience where Mr. Dean had used six inches boulder soling and six inches metalling with $1\frac{1}{2}''$ bituminous carpeting. For rigid surfacing he had used two flat bricks and one on edge, the upper set in cement mortar 1:3, totalling about 11in. in thickness. Over this, 5 in. thickness of 1 : $2\frac{1}{2}$: 5 cement concrete had been used in one or two cases. Instead of brick soling, a hard core of boulder soling, broken slag, and laterite had also been used under a rigid surfacing. The thickness depended upon the Engineer's judgment reinforced by load bearing tests carried out usually on small areas 12 in. × 12 in. though this area is too small for reliable comparable results. Neglecting the tensile strength of the concrete, Brigadier Lang Anderson's formula would require a soling of $9\frac{1}{2}$ ins. under 5 in. of cement concrete, on soil judged after consolidation as capable of taking 2 tons per sq. ft.

Practically all the airfield runways, taxi-tracks and hard-standings constructed on these lines did stand up to the heaviest planes and also to the load imposed by a test apparatus using a Liberator Wheel loaded to 7 tons per sq. ft. A few pavements which failed under test or use were mainly of the flexible type of water-bound macadam over thin soling, with thin carpets or tar surfacing over the waterbound macadam. He considered that the reason for this failure was a deterioration in the bearing capacity of the soil owing to its becoming wet through surface water penetrating through cracks or from a rise of sub-soil water by capillary action.

Some pavements lighter than those deduced from Lang Anderson's formula had also been standing well probably due to the soils being capable of standing a greater load than 2 tons per sq. ft. while dry, particularly after consolidation. A still more likely reason would probably be the over simplification of the process of load spreading that had been adopted.

The Air Ministry, London, have adopted a method of design for concrete runways based on Westergaard's theory as originally published at the 5th and 7th Annual Meetings of the American Highway Research Board in 1925 and 1927 and as revised in the Meetings of 1939* and 1940. This formula in its revised form is

$$f_c = \frac{0{\cdot}275\,(1+\mu)P}{h^2}\left(\log_{10} 11{\cdot}73 + 4 \log_{10} \frac{l}{a}\right)$$

$$= \frac{0{\cdot}31625\,P}{h^2}\left(1{\cdot}0693 + 4 \log \frac{l}{a}\right) \text{ with } \mu = 0{\cdot}15$$

where l = the relative stiffness in inches and

$$= \left[\frac{E\,h^3}{12\,(1+\mu^2 K)}\right]^{0{\cdot}25}$$

f_c = tensile stress in lbs. per sq. in.

P = Applied load in lbs.

h = Slab thickness in inches

μ = Poisson's Ratio = 0.15

E = Young's Modulus of elasticity in lbs. per sq. in
= 3,000,000 lbs. per sq. in.

K = Modulus of sub-grade reaction (Reaction of ground in. lbs. per sq. in. for 1 in. deflections *i.e.*, expressed in lbs. per sq. in. per in.)

a = Radius of circle of contact between tyre and top of slab *i.e.* radius of a circle of area equal to that of ellipse of contact measured in inches.

This involves the determination experimentally of the value of K, the Modulus of Sub-grade Reaction. This varies with the nature of the soil and the extent of consolidation. The experiments were carried out with a rather elaborate apparatus which loads a steel

* See Public Roads, Vol. 20-5, July 1939, pages 83 to 103—Application of the results of Research to the Structural Design of Concrete pavements by E.F. Kelley.

plate of at least 30 in. diameter since uniform results are not obtained when plates of a lesser diameter are used. The formula given above is empirical and not deduced analytically. It is being revised as a result of further experiment. Also the results apply to central loading only: edge or corner loadings are more severe but were not considered in the design of concrete slabs for aerodromes as they involve thickening of edges, steel dowels, etc., which in actual practice are very difficult to carry out.

Mr. N. Seshagiri Rao observed that by applying the intensity of pressure at various depths from the road surface as worked out in the table on page 3 of the paper, the thickness of the metal crust for a road suitable for bullock cart traffic would be much more than that required for taking pneumatic tyre traffic of the same intensity. He presumed that the calculation is only for a minimum thickness of road crust. He felt that in addition to the wheel load, the intensity of the traffic should also be taken into consideration in the design of road structure, as a road which could easily take 100 carts a day with one ton load each, would soon be destroyed if a thousand carts of the same weight use the road every day.

Mr. V. N. Rangaswamy felt that the Author's plea for the design of road structures on a more rational basis would have the support of all road engineers, but unfortunately the intensity of traffic to be carried by the road is not generally accurately known. In fact, the designing of road surfaces and road structures with a certain amount of mathematical exactitude is made difficult by the fact that traffic continues still to be described in terms of "total tonnage of mixed traffic" and no method has yet been evolved by which mixed traffic can be reduced to a common denominator. For instance, the delegates were told the other day that the Madras North Beach Road carried 15,000 tons of mixed traffic a day but this traffic might consist of 14,000 tons of pneumatic tyred traffic and 1,000 tons of iron tyred traffic, or any other combination. The present method of designating traffic in terms of total tonnage per day would not be sufficient for the design of the road crust though this would give an indication of the order of traffic carried. What appears to be necessary is to express the total mixed traffic in terms of "equivalised tonnage" by reducing to a common denominator the several types of traffic.

In a paper read before the Institution of Municipal and County Engineers, Dr. Spielman had attempted to do this by assuming steel-tyred traffic as 10 times more damaging than pneumatic tyred traffic or in other words by taking 1 ton of steel tyred

traffic as equivalent to 10 tons of pneumatic tyred traffic. Though this conversion factor was empirical and has been challenged by engineers, it indicates the direction in which investigation is necessary to arrive at a suitable conversion factor which would enable traffic to be described on a more comparable basis than at present. Till this is done he felt that it would not be possible to design road structures with mathematical exaetitude.

Mr. K. K. Nambiar welcomed the paper as focussing attention on a very important problem in road construction, especially when several erores of rupees are to be spent on roads. In his view, the angle of dispersion of the load would depend on the material of the road structure (flexible or rigid). He did not agree with the Author's statement that when one brick is laid on another the load carried by the upper brick would be distributed uniformly on the layer below.

He referred to the general feeling that if there are no bridges on a road that road could take any load. In olden days, roads were not designed for the loads they had to earry but we had then only bullock carts which did not earry much weight. But with the advent of motor traffic the problem had assumed greater importance.

Mr. U. J. Bhatt felt doubtful about the safe pressure of 2 tons per sq. ft. or 31 lbs. per sq. in. that a well consolidated earth would bear. The bearing pressure would differ according to varying conditions of soil compaction, moisture content, etc., and he felt that the safe pressure should be limited to 3/4 ton per sq. ft. only. He commended for consideration an empirical formula taking into consideration all relevant factors pertaining to specialised road making under Indian conditions.

Mr. A. Shivaraj doubted if a bullock cart would carry 2 tons or a wheel load of 1 ton bearing on about 1.75 sq. in. of road surface imposing a pressure of 1,290 lbs. per sq. in. (Mr McKelvie intervening said that the Council Members had recently seen in Lucknow bullock carts carrying a load of as much as $3\frac{1}{2}$ tons). Mr. Shivaraj continued that the usual load capacity of a bullock cart would be only half a ton. He said that the ultimate crushing strength of 452 lbs. per sq. in. was high on the low side. Also the safe bearing capacity of soil of 2 tons per sq. ft. assumed by the Author was high. For the purpose of designating foundations in soft soils, a safe bearing pressure of 1/4 to 3/4 ton per sq. ft. only should be assumed.

Mr. G. M. Khan gave a brief history of some cement concrete roads laid in Hyderabad to different specifications and said that these

roads had so far been standing up to traffic very well. His experience was that 6 in. and 9 in. cement concrete roads would have a minimum life of 30 to 35 years.

MR. G. M. McKelvie in summing up the discussion said that he felt he should first sound a note of warning. The last speaker, Mr. Khan, had observed that long concrete slabs in Hyderabad had cracked while in Madras they had been successful. Mr. McKelvie was glad this remark had been made because he felt the discussion had not sufficiently brought out the modifications in design necessary to suit local conditions of climate, soil, traffic, etc. Everyone wanted a formula that could be universally applied but this was not easy to arrive at.

In Bengal, Mr. McKelvie had laid about 30 million sq. ft. of concrete slabs with no expansion joints at all and there had been no temperature cracks and no upheavals of any kind. In the U.P., where conditions are very different from those in Bengal, Members of this Congress had seen upheavals on one or two roads although expansion joints had been provided at close intervals. (Photographs of such upheavals are published on opposite pages 248 and 249 of the I.R.C. Proceedings Vol. VII, Part II. January 1941.—Editor).

Referring to the remark of a member that the builders of long ago did not design their arches for heavy loads, but that the same arches had successfully carried modern heavy loads, he said that this was due to the fact that in the old heavy arch designs the dead-load was so much greater than the live load that the old designers overlooked the live load altogether. These designers, however, worked out their arch calculations in very much the same way as is done today. Mr. McKelvie had seen the detail calculations of a bridge containing several spans each of a hundred feet or so built at Kampti 90 years ago. The loads had been very carefully calculated in the same way as designers would do now and the old designers had been very careful about testing whether the sand stone used in the arches could carry the load.

Some speakers appeared to think that elaborate calculations were not necessary and that the old 'rule of thumb' methods which had served so well in the past could serve us even now. Others were inclined to depend too much on elaborate calculations. Mr. McKelvie agreed with the Author that the approach to road-crust design should be much more scientific than perhaps had been the case in the past in India, but he also agreed with the speakers who showed distrust of elaborate calculations because he felt, at the present stage of knowledge of the subject, it would be extremely unwise to apply

elaborate formulae without also applying common-sense and the knowledge gained by experience in considering each problem.

Referring to the Paper, Mr. McKelvie observed that the Author had made no mention at all of the intensity and frequency of the traffic using the road. He had also not referred to such problems as "warping", "edge conditions", "impact," "friction", "soil moisture" and many other factors which, undoubtedly, would influence the design. The Author had, however, clearly stated that his object in presenting his Paper was not to write a comprehensive treatise on road design but merely to call attention to the necessity for scientific design and to provoke discussion. The Author had achieved his object and his Paper had led to a very useful discussion which would, Mr. McKelvie felt sure, be of great benefit to Members and to the Technical Sub-Committees which would later draft specifications for road crust design.

Mr. McKelvie thanked Brigadier Lang Anderson for a Paper which had more than justified itself by provoking the useful discussion which the Members had just heard.

CORRESPONDENCE

Mr. K.A.N. Chetty felt that the Author's design did not take into account impact which is an important factor in roads, unlike buildings where the foundations exert a constant pressure on a fairly homogeneous sub-soil. Intermittent and varying pressures due to wheel loads induce unequal settlements at vulnerable weak pockets caused by defective drainage and have to be provided for. Otherwise, the surface will sink under impact, especially at these weak pockets. An allowance of 50 per cent for impact would be reasonable and this would increase the minimum thickness of crust proportionately.

In treacherous soils like clay, black cotton soil, etc., Mr. Chetty would recommend, from his experience, a layer of sand and gravel over the sub-soil before laying the soling of bricks or stone ballast.

Mr. K.S. Krishnan observed that the Author had not elaborated the principles of design of a road structure in sufficient detail to cover various conditions of traffic and soil. He did not agree with the Author in the classification of road materials as rigid, plastic, and loose. This classification, he considered, should be applied to the binders used in road construction, such as cement,

bitumen, gravel or morum which yield rigid, plastic, or loose pavements.

Impact, friction, and suction referred to by the Author as contributing factors in the design, had not been taken into account. All or a combination of these come into play with different types of traffic; friction and impact in the bullock-cart type; impact and suction in pneumatic tyred-type; and all these in tracked army type of vehicle.

Friction is not a negligible foctor. If μ is the coefficient of dynamic friction on a level road, and R the reaction, R is the horizontal force tending to wear and sometimes tear the road when the loose binder of gravel in a waterbound macadam is displaced. In a gradient, allowance should also be made for the component of the weight along the road surface and the total force would then be $\mu R + R\sin\alpha$ where α is the slope.

Suction, though not possible of being assessed accurately on a mathematical basis, decides the type of binder (cement, bitumen or gravel) to be used for the pavement, and hence the type of pavement, concrete, bituminous surfacings and/or carpets, or waterbound macadam.

Impact varies for different types of road depending on the unevenness of the road surface. On a rough waterbound macadam that due to a fall of 2 in. to 3 in. would not be unusual in wet weather, with deep pot holes. The kinetic energy of the wheel load (mgh) would induce a reacting energy emgh where e is the coefficient of restitution of the type of road. The structure should be able to stand this dynamic force which produces fatigue and internal attrition.

Crushing due to Compression. The Author had taken the effect of straight compression at the foundation level touching the soil, with reference to its safe bearing capacity. But a bending moment is induced by the upward reaction from below, as in the case of grillage foundations, and has also to be reckoned with in the design, though in a non-elastic structure like waterbound macadam with constraint on all sides, this induced bending moment may not be pronounced. Mr. Krishnan felt that further research would be necessary to assess the effect of this upward reaction.

Mr. Md. Farhatullah remarked that for a proper design of the thickness of the road crust, a correct appreciation is necessary of the area of contact of the wheel load, its dispersal to the sub-grade below, and the safe bearing capacity of the soil. He agreed with the Author that the application and release of pressure is responsible for

the disintegration of the sub-structure, but no remedy had been suggested except the renewal of materials. From his experience, Mr. Farhatullah would suggest a layer of well boxed material such as shingle, between the road crust and the sub grade, as a possible remedy. This intermediate layer, being incompressible, would not yield under pressure, and at the same time would prevent the disintegration of the sub-grade from the impulsive forces due to a moving load, by its comparatively limited freedom of movement. This, in fact, would act as a damping course in absorbing the impact and keep the sub-grade intact, thus giving a longer life to the road.

Mr. J. T. Mehta stressed the importance of a sound foundation for the thin wearing coats usually adopted, but felt that a safe bearing pressure of 31 lbs. per sq. in. of the compacted subsoil assumed by the Author was on the high side especially with the seasonal varying conditions of the soil at shallow depths from the surface, and the churning action of varying moving loads. The values adopted by the Massachusetts Commission of 1901, after careful investigation, are 25 lbs. per sq. in. for gravel and 4 lbs. per sq. in. for poorer clays. For an average alluvial soil, well drained, he would limit this to 20 lbs. per sq. in.

Mr. A. S. Adke gave his experience that, in the Dharwar District, a 3 in. metal crust ordinarily provided for the wearing coat, failed under intensive military bus traffic. He felt that administrations responsible for roads should have control of traffic using the road with a view to limit this traffic to the capacity the road could safely stand. In his view, the speed of the moving loads using the road should also be taken into consideration in the design of the road structure.

Rao Bahadur K. Tirumalaiswamy Iyer considered that greater importance should be given to the selection of the right type of surface, which would prove economical over a period of 30 years taking into account both first cost and subsequent maintenance. He stressed the importance of drawing fully on the experience gained, and the data available on the relative performance of different types of road crust for similar conditions of traffic, taking also into consideration the availability of suitable indigenous materials.

Referring to the failure of brick pavements in certain situations, he remarked that the Author had not clearly stated whether the failure was due to wear, or settlement, though from the solution suggested, it appeared to be due to the latter. If so, he felt that a much cheaper remedy would be to replace the $1\frac{1}{4}$ in. to $1\frac{1}{2}$ in. carpet by a 3 in. macadam surface.

The considerations for the foundation of a building are different from those of a road. In the case of the former, the only point is to limit the pressure on the soil to what it can bear (though in localities subject to earthquakes, other factors complicate the issue). But in a road structure, several factors influence the design, such as the nature of the soil and its condition, type and intensity of the wheel loads, availability of suitable materials at economic cost, construction and maintenance costs, and other topographical and climatic considerations.

He referred to several instances where proper selection of one type of road pavement in preference to others had proved economical. The design should also take into consideration the emergency traffic of short duration which would require less costly pavements, and permanent traffic requiring a lasting pavement. With the useful information disseminated by the Indian Roads Congress and other technical bodies, and the valuable experimental data available on the relative performance of different types of road for identical conditions of traffic, it is not very difficult for any engineer to make a right choice. In choosing the type of surface the following points should be considered:—

(i) Availability of materials, their suitability and cost (Laboratory tests for French coefficient should be made).

(ii) Traffic—nature, intensity, and duration. (Diversion roads, service roads, and roads for emergency traffic of short duration require to be treated differently).

(iii) Equivalent traffic intensity reduced in terms of either steel-tyred traffic or pneumatic tyred-traffic.

(iv) Facilities for carrying out a particular type compared with the volume of work—special plant for a short stretch of road would be difficult, and uneconomical except in the case of experiments.

(v) Use of indigenous materials even if slightly more costly.

(vi) Comparative cost of different types, (including construction and maintenance) over a period of say 30 years.

(vii) Ways and means of financing improved types of surfacing which are found economical as in (vi).

(viii) Considerations other than cost for adoption of an improved type, *e.g.*, provision of improved surface over important bridges, in town and village limits, near hospitals, educational institutions, etc., to avoid dust nuisance.

would be interesting to know how the brick road was constructed. He drew the attention of Members to Searl's contribution on "brick roads"†, wherein the importance of a proper cushion for the bricks has been dealt with.

† Searl's contribution on "Brick Roads" printed in pages 562-563 of Kempe's Engineer's Hand book—1934 Edition.

DISCUSSION ON CALCULATIONS OF THE STRUCTURE OF ROADS

Brigadier Lang Anderson, the Author, in his reply sent from England where he was on leave, expressed his satisfaction that so many members had given considerable thought to a Paper which was professedly rudimentary and had dealt inevitably in a superficial manner with a very wide subject. He was particularly grateful to the Chairman for introducing the Paper in his (the Author's) unavoidable absence, and for summing up the discussion.

2. Being on leave and having no ready access to reference books, the Author was not in a position to give a detailed reply to the comments of members who had either written or spoken on his Paper. In any case the Author considered that no detailed reply was necessary and that it would be sufficient if he confined himself to a few general remarks.

3. It was evident that he had not made two points in his Paper very clear. Firstly, in applying the terms "rigid", "plastic", and "loose" to the materials of road construction, the intention was that those classifications should apply to the road pavement as a whole (exclusive of the earth formation) and not to the individual materials of road construction (stone, cement, bitumen, etc.). Secondly, the design of a brick road was chosen as an easy example of how one might set about calculating the structure of a road, and not as a perfect example of how a brick road should necessarily be constructed. Hence detailed criticisms of such factors as the pressures adopted, were not really relevant. But some general principles were raised which require comment.

4. **Firstly**, certain members objected to the omission of impact from the calculations. The Author had taken for granted that impact would have already been included in any figures adopted by the engineer when estimating the safe crushing strength of the materials he proposed to use. In bridge design the impact factor is reduced as the size and weight of the bridge increases, and as the moving load becomes a smaller and smaller proportion of the dead load. In the case of a solid road, the weight of the moving load is such a small proportion of the weight of the portion of the road over which it is moving, that the effects of impact, except to the surface, are negligible. The solution to impact effects on the surface can be achieved by making the surface really flat, without undulations, as all good roads should be.

5. **Secondly**, certain members objected to the omission of the intensity of the traffic from the calculations. Again, consider bridge design. One designs a bridge to carry certain loads per

square foot of surface, or to carry a sequence of certain axle loads, but one does not vary the design of the bridge *structure* because one expects those loads to be imposed once a minute, or once an hour, or once a day. With very frequent traffic one would put a stronger wearing surface on the bridge deck than if the traffic were only occasional. The extra weight of the stronger wearing surface, and not the frequency of the traffic, might affect the design of the bridge structure. The same principle should apply to the calculation of the structure of a road.

6. Thirdly, members doubted whether *brick on flat* was "stronger" than *brick on edge*, one member pointing out that the moment of resistance on edge is greater than that on flat. (The ratio actually is 3 to 2) But in a brick road the bricks should be bedded so solidly as not to be subjected to a bending moment but to crushing, and it was only crushing strength that was quoted in the Paper.

7. The Author was himself surprised when he first saw the crushing strength figures in the M.E.S. Handbook and the only explanation he could think of after examining a number of bricks, was that hand moulding (which is usual in India) often caused horizontal stratification of the clay and hence weakness when a load was applied perpendicularly to the planes of cleavage, i.e. when the load was applied to bricks laid "on edge". The point is well worth further investigation by experiment, as a brick laid flat obviously must distribute its load more than a *brick on edge*, and distribution of load is so vital to preventing subsidence of the road structure.

8. Fourthly, a few members quoted one or two instances where roads built according to "accepted practice" and, apparently, by rule of thumb methods, had stood up well to traffic. It would have been lamentable if long experience and practice had not produced such roads ! But the instances were valueless as they were not compared with similar roads designed by "calculation methods" and there was nothing to show that the materials used might not have been applied differently to provide a much better road.

9. In conclusion, the Author observed that the whole object of the Paper was to eradicate an attitude of mind which accepted "existing practice" as "good enough" without even trying to assess scientifically why certain methods were successful, and whether better methods could not be evolved.

NINTH SESSION—MADRAS-FEBRUARY 1945

ADHESION OF BITUMINOUS BINDERS TO STONE METAL AND THE USE OF SLAKED LIME FOR TREATMENT OF WET AGGREGATES

BY C. J. FIELDER

(PAPER IX—99)*

DISCUSSION

(Monday, February 12, 1945)

Mr. I. A. T. Shannon (Chairman), in inviting Mr. C. J. Fielder to introduce his Paper, said that this Congress differed from most other Societies of a pr dominantly professional nature in that when it was formed provision was made in the Memorandum of Association for the admission of persons who were connected with road construction and development for business reasons.

Speaking on behalf of the Business Members, he felt that the full discussion and interchange of ideas afforded by these meetings had been of much benefit to them. He believed that the "leavening" of Business Members at these meetings, and on the Council had not been without value to the rest of the Congress. If proof of this were needed, it was supplied by the present Paper under discussion on "Bituminous treatment of Wet Aggregates" written by Mr. C. J. Fielder who had succeeded Colonel Sopwith as General Manager of Shalimar Tar Products, Ltd.

Mr. Fielder had dealt with his subject in a most thorough and scientific manner and, while some members might be more concerned with the practical aspect of what he had written, he hoped that those who were competent to speak on the scientific aspect would also contribute to the discussion so that the maximum benefit might be obtained from the Author's work and so that the printed Paper and debate would form a comprehensive review of the subject.

Mr. C. J. Fielder, the Author, in introducing his Paper, said he wished to remark on the true functions of bituminous binders as there was apt to be some misconception in the matter. The role of a bituminous binder is to provide a plastic setting for the stone metal which comprises the main body of the surfacing. This plastic setting is essential to assist the stone metal to with-

*Published on Pages 7 to 54 of Part C, Vol. IX of I. R. C. Proceedings.

stand and distribute the impact and load of the traffic over the road bed. The binder is not intended to carry the load itself: it is merely designed to supply this plastic setting whereby metal can "take it" without destruction or disturbance. The binder has also to protect the stone metal from climatic conditions and ensure water-proof conditions. To fulfil the above role successfully, a binder must retain its resilient and plastic properties for a considerable length of time. It must not become brittle and it must adhere strongly to the stone metal. It is this latter property of *adhesion* which has been dealt with in the present Paper.

The first part of the Paper is actually a 'resume' of the physical theories underlying the mechanism of adhesion which he had tried to present as simply and clearly as possible. The second part describes the methods which various investigators had adopted for detecting the quality of adhesion between binders and stone metals. The third part of the Paper deals with means of promoting binder adhesion. It contains the 'proof of the pudding' and is probably the part which will be most interesting to those present at the discussion.

It is a natural step, on the basis of the foregoing theories, to try to evolve more satisfactory surfacing treatments and in particular to evolve methods which can be used under wet weather conditions. Such conditions are usually considered, if not actually fatal, at least extremely unfavourable for bituminous surfacing work but the War has tended to bring strongly to notice the desirability of continuing to try to improve methods of road surfacing which can proceed with a minimum amount of interruption from seasonal conditions. The methods described in the third part of the Paper may therefore prove to be of some value to road engineers in this country.

The Author showed the Members some samples of coated stone chippings which illustrated the effect of lime in promoting the adhesion of road tar to wet stone chippings of various types.

Rai Sahib Fateh Chand explained how, with the timely use of lime, he had been able to save material, labour, and the hire charges of a roller when a sudden outburst of rain interrupted surfacing work. He had prepared the road for surfacing, heated the binder, and was about to start the work of surfacing when it began to rain. Mr. Mahabir Prasad, Chief Engineer, U.P., suggested the use of lime to get over such difficulty and this was adopted. Lime was spread over the road surface with a brush and the surfacing work was continued. The experiments had been successful and the surface had been standing for over three years. With improved technique and more research work in the bituminous treatment of

wet aggregates, surface treatment could, he felt sure, be carried on satisfactorily even during the rainy season. He therefore welcomed the Paper as very opportune.

Mr. F. E. Cormack thanked the Author for an erudite and interesting Paper on a very important subject. After reading the Paper, he considered that the Senators of his University made a mistake in directing him to study Inorganic Chemistry instead of Organic Chemistry. He was not in a position to criticise the Paper, but he would like to enquire whether, in the course of surface painting, the lime treated chippings were brought sufficiently into contact with the binder that was used. He had especially noticed that, as stated on page 33, mere immersion of the lime treated chippings into hot tar did not produce adequate wetting by the tar.

Mr. R. G. Perry congratulated the Author on the high technical standard of his Paper. He mentioned, as a matter of historical interest, that lime had been applied to road surfaces as far back as 1910 by Professor Hubbard in America. Professor Hubbard found that water-bound macadam roads made of a certain type of granite would not consolidate and bind satisfactorily but when he applied lime to the surface and damped it before consolidation, the binding was much improved. This was stated to be due to the mortar produced by the action of lime on the granite. The Author has carried this a step further. Apart from the action of lime on the tar, it is reasonable to suppose that lime acts also on the stone and forms a kind of mortar on the surface and this layer of mortar may be the explanation of the check to the initial penetration of the binder which Mr. Fielder had experienced.

As regards adhesion, the chemical affinity of binder for stone and the physical effect dependent on the surface of the stone should both be considered. Adhesion tests show that different results are obtained with the same type of stone from different sources; thus the adhesion test is not alone sufficient to indicate the extent of penetration of binder. It is necessary to use, as Mr. Fielder had pointed out, a binder with low surface tension and low viscosity but the binder should set to a high viscosity shortly after penetration.

The basis of the good adhesion produced by lime treatment of wet aggregate is said by some authorities to be due to the extraction of water by the formation of a water-in-oil emulsion by the action of calcium salts. It has also been stated that caustic soda can be used in place of lime. The theory suggested by the Author would therefore appear to require some modification. In the Corporation Emulsion Plant which the Members saw the other day, a small percentage of caustic soda produces the normal type of road

emulsion. This is a oil-in-water emulsion and not water-in-oil emulsion as produced by calcium salts.

It is generally understood that a normal road emulsion can be used with advantage on a wet aggregate because of its low surface tension and low viscosity. In fact, the specifications usually suggest that the road surface or aggregate should be damped prior to the application of an emulsion. This suggests that Mr. Fielder would get results as good as those given by the lime treatment if he used a quick breaking tar emulsion on wet aggregates. It would be very interesting to have some trials on the use of quick breaking tar emulsion and check the results as it is only by such trials that one could expect to make progress.

Mr. **Shannon** observed that he had been asked by the Author to supplement what had been put in the Paper by saying something on the practical work that had been done in this country on the use of lime with bitumen, as distinct from road-tar, binders. The Author on page 36 of his Paper mentioned the work done in the United Kingdom by Lee and Carter and had referred to the full scale field trials that were laid on the Colnebrook by-pass in October 1942. Technical development in this country has not lagged behind that of other countries. Full scale trials were laid by arrangement with the Central P.W.D. early in April 1942 on the Delhi-Meerut section of the Grand Trunk Road at Sahadara about 2½ miles from Delhi. This trial was witnessed, amongst others, by Sir Kenneth Mitchell, Mr. Vesugar and the Congress Secretary, and the road is still standing well after nearly three years of heavy lorry traffic. The work consists of a light-1¼ in. consolidated-precoated stone carpet with Delhi-quartzite stone saturated with water to the maximum extent possible. At the time of laying, copious quantities of water were also added to the carpet before, during, and after consolidation. The adhesion of binder to the stone was entirely complete, so much so that it is difficult to avoid the conclusion that with some stones, the so-called "wet stone process" does result, by the chemical action of the calcium compounds formed, in better adhesion between the binder and the aggregate than can be obtained with a binder of similar viscosity and sun-dried stone.

The idea of wetting stone aggregates with water in order to get it subsequently well coated with hot binder may seem illogical but there is still a lot to learn about the function of binders and their chemical treatment of flexible binders. He was interested to note that a recent chart showing road research work in progress and planned at Harmondsworth included reference to the "wet stone

processes." A "wet sand process" has now been included in the proposed investigation. The Author has made a passing reference to this on page 37 paragraphs 2 and 3. In Mr. Shannon's view, the process appears to offer a very promising field of work to road engineers in this country where sand and shingle are on the whole freely available.

The wet stone process consists essentially of so treating the aggregate or road surface (and in the case of bitumen, the binder also) that it possesses a preference for bitumen in the presence of water. The "wet sand" process is different. In this, one gets a "structure" formation which derives its strength from physio-chemical action, and it is thought, because of thixotropy. Although the results of field scale trials on this process are promising, the process is as yet in an early stage of development. It is understood, however, that the process has been developed on important military works in the U.K. The speaker had recently seen a note on stability tests carried out on samples of "wet sand" carpets in which it was reported that the stability was *40 times* that of sheet asphalt. There is, therefore, a possible development of a new form of construction which will possess stability in the region of that obtaining in rigid forms of construction, and which will at the same time retain essential resiliency, and be low in first cost.

Returning to the present Paper, the Author has stated that lime alone would be sufficient for increasing the adhesion of tar to chippings while, in the case of bitumen, the addition of an acid is also necessary to achieve a similar result. This is true. When this process was started in 1941, cresylic acid (a chemical imported from U.S.A. under Lease-Lend) was used. This was a very efficient agent and was used in the Delhi-Meerut road test referred to. Due to the difficulty in obtaining this material, indigenous substitutes had to be found for large scale use in certain military works in the Eastern area in the 1942 monsoon. One of these is creosote of a specific light tar acid content, but this is also in short supply. Sulphonated castor oil (better known as Turkey Red oil) was next tried and found to be effective. As this could be made available, it was for a while standardized. There is, however, a difficulty in the use of Turkey Red oil as it contains a percentage of water and cannot be added into the hot bitumen in the boiler, but must be applied to the lime treated aggregate or road surface separately, thus adding an extra stage to the work. Further experiments carried out in 1943 indicated that blown rapeseed oil was an efficient material for this process and, like cresylic acid, can be added to the bitumen in the boiler. This oil can be obtained fairly easily from oil mills in the United Provinces. He would suggest the use of blown rapeseed oil for any tests with bitumen binders.

Another point brought forward by Mr. Shannon was the application of this process to direct surface dressing over a road made of laterite metal. Results of this are promising.

Mr. A.W.H. Dean thanked Mr. Fielder for his interesting and valuable contribution to the literature of bituminous binding materials. He considered it a really scientific and practical Paper of considerable interest. He expressed satisfaction that India and Indian Engineers had been pioneers in this process and that the results so far had been satisfactory. He confirmed Mr. Shannon's remark that the experiments on the Delhi-Meerut road were satisfactory. While in England a few months ago, he had seen the results of the "wet sand" process and was assured by the Director of Works, Air Ministry, that with the "wet sand" process it was possible to have a surface which would resist a 100 per cent. locked wheel turn without disintegration—a very severe test.

Though, even during monsoon, construction work could be carried out with emulsions, it was in Mr. Dean's opinion not a very practical method because it involved transporting larger quantities of emulsion than of straight tars or bitumens. The method described in the Paper increases the working season for road surfacing works.

He testified to the successful results obtained everywhere by the use of lime and tar in road surfacing work with wet aggregates and he considered the process simpler in many cases as lime is more readily available material than any of the oily chemicals which are necessary for the wet aggregate process with bitumen.

In addition to the function of binder as a plastic setting by which the metal can take the load of the traffic and transmit it to the base without disintegration and deterioration, there is another important use of bituminous materials in road surfacing, viz., that of water proofing the subsoil and so retaining its load bearing capacity.

Mr. N. V. Modak stated that his experiments in the Bombay Corporation with "wet sand" and "wet stone" processes had not been successful and the return was not adequate. He, however, agreed after hearing of the successful results obtained elsewhere to carry out further trials as soon as asphalt was available on a larger scale.

Mr. C. J. Fielder, the Author, in reply to the points raised

in the debate, said that one criticism he had received in writing (page 28) questioned whether it would not be possible to improve the binder rather than incur greater expenditure in adopting costlier specifications for surface treatment. He considered that the additional cost of using the small quantities of lime required by the new specifications would not be more than a very small percentage of the total construction cost. The work under wet weather conditions could not, of course, proceed as rapidly as in dry weather. The small additional cost should not deter anyone from adopting the wet aggregate method.

He wished to emphasize that the success of the process was due to the slaked lime coming in contact with the moisture associated with the metal before the bitumen or tar was applied.

With regard to the interesting point raised by Mr. Cormack in connection with elimination of water from the surface of the stone in the case of surface dressing, he considered that the movement induced by traffic would be sufficient to bring about the mechanical action which is prescribed in the case of premixing.

He felt grateful to Mr. Perry for his very interesting remarks. He imagined that some mortar action with lime probably takes place though he did not yet know exactly what happens at every stage. The main thing is that tar should be available in adequate quantities to "wet" the surface of the stone metal in the early stages. He did not recommend the use of caustic soda in place of lime for the reason that it reduces the viscosity of the binder at higher concentrations although it is seen to promote wetting in small scale tests. The action of emulsions is somewhat different in that low initial viscosity is followed by quick setting on "breaking", but this does not help in eliminating the water from the stone-binder interface. For this reason, although tar emulsions in England are known to have yielded satisfactory results, their use has not been stressed in connection with wet aggregate treatment. He would suggest Mr. Perry should try the use of emulsions with lime.

He was also grateful to Mr. Shannon for his supplementary remarks on wet aggregate treatment with bitumen. Cresylic acid is one of the main ingredients in tar acids and it might therefore be anticipated that its use would be of great value in the wet aggregate treatment with bitumen to supply the other side of the chain which lime requires to reduce adhesion tension at the stone-binder interface and to promote effective adhesion. Cresylic acid is manufactured from Coal Tar in this country but is subject to control and is not available at present for road construction.

The additional function of bituminous surfacing in waterproofing the road bed suggested by Mr. Dean is very important. He felt glad that Mr. Modak of Bombay had become a convert to lime treatment and hoped that other Municipal and District Engineers would follow his example and adopt wet aggregate repair work during the monsoon so as to carry out repairs expeditiously as soon as signs of deterioration first appeared.

Mr. Shannon, the Chairman, thanked Mr. Fielder on behalf of the Society for the trouble he had taken to prepare the lucid, scientific, and practical Paper which has been discussed. After the war, or possibly sooner, road research is to be carried out in India on an intensive scale and a Road Research Institute is proposed to be set up with a Director in charge. When the latter takes up his post, he will find that on one item of his work his brief has already been largely prepared for him, thanks to the time and trouble that Mr. Fielder has spent in writing this Paper.

[Editorial : Report of the tests on the adhesivity of tar and bitumen with and without lime and for Turkey Red oil conducted at the Government Test House, Alipore, and issued to the Chief Engineers of Provinces, by the Indian Roads Congress, is reprinted as Appendix I on pages 31—35

CORRESPONDENCE ON BITUMINOUS TREATMENT OF WET AGGREGATES

Mr. H. K. Nivas while congratulating the Author on producing a very interesting Paper on certain experiments carried out with bituminous materials and slaked lime, considered that a few points required clarification.

It would be interesting to know whether the stone chippings used in the wet aggregate experiments on runways were of the *hydrophilic* type and whether the use of gravel (bajri) instead of stone chips would have had any different effect. Also whether different quantities of lime and tar would have to be used for different kinds of aggregate.

Mr. N. Das Gupta considered the Paper an excellent one on a most interesting subject. The use of wet aggregates becomes unavoidable in places where the rainfall is heavy and the monsoon starts

early, and where there are occasional heavy showers even during summer or winter months.

While working as a road engineer for the Standard Vacuum Oil Co., Calcutta, he had carried out in the road research laboratory of the firm a large number of experiments on asphalt-water-affinity on stone metals commonly used in India. A brief outline of the experiment conducted and the results obtained was given by him and is recorded below.

> ASPHALT-WATER-AFFINITY TEST. The apparatus for the test consists of a wide-mouthed glass bottle with a cork stopper through which pass two glass tubes for blowing air into the bottle. Air is forced through one tube and allowed to escape through the other.
>
> The bottle is half-filled with water. One gram of stone to be tested, (crushed to the size of coarse sand) is mixed with a fixed percentage of a bituminous binder. This premixed stone grit is then introduced into the bottle and air is blown in. The time up to the point when stripping of the asphalt starts is noted by means of a stop-watch. The blowing is continued for half an hour, water and stripped asphalt floating in the water are then carefully decanted, and the stone grit with residual asphalt on it is carefully dried and weighed. The difference in weight gives the amount of asphalt stripped by flowing, and this gives an index for the affinity of the aggregate to water.

As a result of nearly 30 tests, Mr. Gupta's conclusions were that stone containing clay or lime such as trap, basalt, limestone, dolomite, etc., have a stronger affinity for asphalt than water, *(hydrophobic)*, while stone containing silica such as granite, quartz, etc., are stripped of asphalt within 5 minutes of blowing *(hydrophilic)*. If, however, hydrophylic aggregates are soaked first in lime water and then coated with asphalt, no stripping occurs thus indicating increased adhesion of bituminous binder to wet aggregates in the presence of lime. For the benefit of Members interested in the details of these experiments, he would contribute for the next session of the Congress a Paper on asphalt-water-affinity tests, with Indian aggregates.

(3). Mr. S. A. Kikkeri in his written comments quoted the remark made by Mr. A. C. Hughes in his Paper on "Some of the problems of surface dressing read before the joint meeting of the Chemical Industry and the Institution of Municipal and County Engineers :—

> "I do not profess to be a chemist, but on the other hand, I can claim to have some knowledge of the problem of surface dressing from a practical point of view. After all, the best way of approaching a difficulty of this kind is for the Engineer to state his problems and ask the Chemist to solve them. Sometimes the Chemists are apt to produce tars and bitumens based on theories of their own without real regard being paid to actual problems.

Mr. Kikkeri proposed to confine himself to the practical aspect. The Author had very rightly stressed that the construction of road surfaces required careful selection of both *materials* and *specifications* with reference to *local conditions* and traffic demands. In addition, the Author claimed that the object of the Paper was to discuss "the means by which adhesion between binders and stones can be improved." Dusting the road surface and aggregates with slaked lime was suggested as a remedy.

Mr. Kikkeri considered that instead of asking road makers to adopt costly specifications for materials and laying to suit the binder, it was time the Chemist was asked to improve the binder to suit the materials and local conditions. One such improvement would be a "filled binder", with lime or other pulverised coal dust of specific fineness and quantity added at a particular temperature.

He did not agree with the Author in the statement that the addition of dibasic fatty acids of high molecular weight to tars is one of academic interest only. He contended that the extracts from various authorities on the subject (extracted below) would show on the contrary that such additions are becoming more and more of practical application, as is evidenced by the increasing use of "filled tars" in other countries with promising results.

1. **Roads and Road Construction.** (Jan. 1, 1935)

(a) "It is a fact that broadly speaking, the higher the silica content of an aggregate the less its affinity for the binder, be it tar or bitumen, while the basic granites—used in its generalitic term—has a better affinity. Variations, in other respects are also of importance, like the porosity of a stone and the obstinate retention of extremely thin films of moisture Perhaps, the reason why tar enables the binder to adhere firmly to hydrated lime is on account of its alkaline reaction and the affinity of tar of alkaline bodies. If this impression is correct, a further improvement in adhesion could be brought about by adding to the binder a small amount of cheap crude organic acid like common rosin which is freely soluble in tar and bitumen."———(Mr. A. Wolfe.)

(b) "The addition to tar of a powdered asbestos filler, extracted dust, etc., indicates a cumulative effect. Consistency is improved by adding small proportions of linseed oil, maize oil, cotton seed or olive oil"——— (Abstracts Jan 1, 1935).

2. **Tar Roads by A.C Hughes**—(Road Makers Library)

(a) "The addition of rosin in various forms. or of metallic resinates, to tars has been proposed and it has been claimed that better adhesion has been shown by the mixtures, also that the durability of the tar has been improved.. .road trials have given results from which no definite advantages accruing from addition of rosin could be adduced."

(b) "A process that produces from tar a highly viscious product is a Bitural process in which a tar.. . .is treated with a proportion of formaldehyde and then subjected to air blowing. The product has been used extensively. in Australia for road surfacing, but reports results of

are few and contradictory. An experimental stretch of road was laid down......using Bitural as binder. This was reported to be in excellent condition two years later."

3. **Roads and Road Construction.** (September 1, 1934.)

"A particular French development is "Fillerized Tars" in which upto 50 per cent. powdered coal, and also limestone and other dusts, have been used. The large-scale experiments are very promising."

4. **Roads and Road Construction.** February 1, 1936—Abstracts—Filled tars by Duliez.

"The use of filled tar for surface treatments constitutes an improvement over that of plain tar, each season provides practical confirmation of this fact..... . Due to the absorption by the filler of small quantities of heavy oils, enough to ensure sufficient plasticity, a dressing with filled tar will age much more slowly than with plain tar."

(Mr. Kikkeri then went on to discuss the advantages of using "filterized tars" of various types and quoted the views of a number of authorities on his subject As the Paper under discussion deals with the subject of adhesion of binders to wet aggregates, the valuable remarks of Mr. Kikkeri are not considered relevant and have been omitted from this record of the written contribution to the discussion The question of fillerized binders will no doubt form the subject of a subsequent paper to this Congress—Editor).

Mr. C. J. Fielder, the Author, sent the following replies on the comments made on his Paper by correspondence :—

Reply to comments by Mr. H. K. Nivas.

The stone metal employed in the case of experiments on runways described in the last part of the Paper were almost entirely carried out with Pakur basalt trap metal. This metal is definitely hydrophilic and the improvement achieved with lime in respect of adhesion is certainly most marked. Certain small lengths were also carried out with local stone metal of poor quality granite in one or two projects and here again improvement in adhesion was well in evidence.

The subject of adhesion between Pakur metal and bituminous binders in the presence of lime has been investigated by the Government Test House, Alipore, on behalf of the Chief Engineer, P.W.D., Bengal. The results of this investigation were circulated† to all Chief Engineers by the Secretary, Indian Roads Congress, in his letter IRC of II 12-7-44. It may be stated here that the tests for adhesion employed by the Government Test House do not

†Printed as Appendix I on pages 31 to 36—Main conclusions of the tests are printed on pages 32-33.

conform exactly to the tests described in the Paper, but this does not affect the general conclusions but merely the figures employed to represent the degree of adhesion.

Laboratory Tests for adhesion have been carried out with Dalbhumgarh gravel which, the Author believes, is the type of gravel of which Mr. Nivas refers as being available in Bihar. While this gravel is also hydrophilic, the use of lime was found to give definite improvement in regard to adhesion with the quantities of lime and tar recommended in the general specification given in the last part of the Paper.

No comments on the remarks by Mr. Das Gupta.

Reply to Comments by Mr. S. A. Kikkeri.

Mr. Kikkeri objects to the method proposed for improving adhesion involving the use of slaked lime as described in the last part of the Paper on the grounds that it increases the cost of material and labour employed in the surface treatment of roads. He would prefer that any improvements should be incorporated within the road tar itself rather than involve a separate application to the surface.

So far as the Author is aware, no filler has yet been discovered which has been definitely proved to have the property of markedly improving adhesion when incorporated in a bituminous binder.

As regards the extra costs of slaked lime treatment, it will be seen from the figures given in the Paper for the slaked lime required that the relative amounts are very small, and it can be safely assumed that adoption of this treatment will not increase the overall finished cost of the surface treatment by more than 5 per cent. This figure cannot be considered to be large enough to act as a deterrent to the adoption of this method of surfacing which has been found to yield such markedly improved and advantageous results.

If the slaked lime is mixed with the road tar before the application of the latter to the road surface it does *not* achieve superior adhesion between binder and stone in the manner described in the Paper, and similarly with the other fillers which Mr. Kikkeri refers to in his comments. While it is not disputed the certain fillers do confer superior qualities on bituminous binders, it has not been claimed that such qualities include that of adhesion to stone metal and the effect of such fillers therefore falls outside the scope of the present Paper.

The paper on "The Use of cold and wet aggregates in Bituminous Construction for Roads and Aerodromes" By A.R. Lee and H.J.E. Carter referred to in Mr. Fielder's paper has now been published as Institution of Civil Engineers, Road paper No. 12.—Editor.

APPENDIX—I.

Note on *Adhesion Tests* of binder (tar and bitumen) to stone chips, (fine grained basalt) both *dry* and *wet*. with varying proportions of *fat lime*, *Turkey Red oil* and *Cement*.

(Issued to Chief Engineers of Provinces with I.R.C. letter No. 11, dated 12. 7. 44. 7)

Tests were carried out in the Government Test House at Alipore to determine the degree of adhesion between

I. (i) tar and moisture-free dry aggregates
(ii) tar and aggregates mixed with water in varying proportions
(iii) tar and dry aggregates mixed with slaked lime in varying proportions
(iv) tar and dry aggregates mixed with both water and slaked lime in varying proportions.

II. (v) bitumen (80-100 penetration) and moisture-free dry aggregates
(vi) bitumen and aggregates with water in varying proportions
(vii) bitumen and dry aggregates mixed with slaked lime in varying proportions
(viii) bitumen and dry aggregates mixed with both water and slaked lime in varying proportions
(ix) bitumen and dry aggregates mixed with water, slaked lime and Turkey Red oil in varying proportions
(x) bitumen and dry aggregates mixed with water and portland cement in varying proportions.

The results of the tests are shown in the accompanying graph* and statement†.

2. **Tests With Tar.**

The characteristics of the tar used were:—

(a) Viscosity determined at 40°C by B.R.T.A. Viscometer.	115 seconds
(b) Tar acids	0.7 per cent. by Volume

*See page 35. †See page 34.

Tests were carried out in accordance with the Standard German method given in DIN 1095. The size of the stone used for the test, was 0.2 to 0.6 m.m. i.e., 0.0079 in to 0.0236 in and was obtained by crushing Pakur basalt stone chips and sieving so as to pass through B.S. Mesh No. 25 but to be retained on B.S. Mesh No. 72. The proportion of aggregates and binder was 71:29 by volume.

3 Adhesivity was measured by boiling the mixed stone and binder for one minute in distilled water and then Sodium Carbonate solution of increasing concentrations until separation took place, the power of adhesion being greater the higher the strength of solution required to cause separation. The adhesivity of the stone to the binder is considered *unity* if separation just takes place, at a concentration of N/256 of Sodium Bicarbonate solution.

Conclusions drawn.

I. *TAR.* (1) Tar adhesion to the stone supplied was not good initially and became poor in the presence of moisture of more than 7 per cent. by weight

(2) When the percentage of moisture present in the stone was small (say 1 to 3 per cent), the addition of a small percentage of slaked lime greatly increased the adhesivity.

(3) When the percentage of moisture present in stone was moderate (6 to 16 per cent.) or high (40 to 50 per cent.) the addition of slaked lime in increasing percentages (upto 15 to 25 per cent.) progressively increased the adhesivity (Water when present in excess of 40 per cent did not adhere to the surface of the stone but started trickling).

(4) The addition of increasing percentages of slaked lime (upto 25 per cent. by weight) to bone-dry stone progressively increased the adhesivity of the stone to tar.

II BITUMEN.

(1) The adhesion of the bitumen tested with the stone supplied was initially good.

(2) Its adhesivity to the stone progressively decreased with increasing moisture content and became poor when the moisture content was increased to 20 per cent.

(3) With 20 per cent. by weight of moisture in the stone, the addition of increasing percentages of slaked lime progres-

sively increased the adhesivity which was further improved by the addition of Turkey Red oil to slaked lime, the adhesivity becoming very good when 6 per cent. of slaked lime and 3 per cent. of Turkey Red oil had been added. In the case of stone with water trickling from its surface (40 per cent. water content or more by weight), the same progressive increase in adhesivity was noticed with increased addition of slaked lime and Turkey Red oil, the adhesivity being very good when the slaked lime added was 10 per cent. and Turkey Red oil 6 per cent.

(4) On repeating the adhesivity tests with either tar or bitumen by replacing the slaked lime with portland cement, appreciable improvement in the adhesivity was noticed in each case but not to the same marked extent as in the case of the tests with slaked lime.

DISCUSSION OF THE TEST RESULTS

The results obtained in the tests with slaked lime appeared to be primarily due to the formation of water-insoluble soaps, the presence of which aids the adhesion of tar or bitumen to the stone by reducing the interfacial energy between the binder and the aggregate and increasing the interfacial energy between the binder and water, which is thus easily eliminated. It is stated that this method has been the basis of certain U. S. patents for mixing binder with wet aggregates.

As regards the results obtained in the tests with addition of cement, the explanation for the slight improvement may be found in the presence of free lime in the portland cement used; it may also be due to the fine powders of portland cement increasing the viscosity of the binder and thus increasing the adhesivity to a certain extent.

Statement showing the test results regarding the Adhesivity of Tar and Bitumen to Stone in various proportions of Lime Turkey Red oil, and water.

ADHESIVITY OF BINDER TO STONE CHIPS.

Water Percentage by weight of binder	TAR: With lime expressed as percentage by weight of Tar.				BITUMEN: With lime and T.R. oil expressed as percentages by weight of bitumen — Lime					Lime & T. R.† oil		
	0	1	5 to 10	20 to 25	0	1	4 to 6	10	20	L—1 T R.O. 2 to 4	L—4 T.R.O. 4 to 6	L—20 T.R.O 2 to 6
0 (Dry aggregate)	1	5	7	8—9	8	8	9-10	—	—	—	—	—
1	1	6	9	—	8	—	—	—	—	—	—	—
3	1	7	8	—	8	—	—	—	—	—	—	—
6	1	7	8	9	8*	—	—	—	—	—	—	—
8	0	6	8	9	7@	—	—	—	—	—	—	—
15	0	6	7	9	1	7	8	—	—	7	9	—
20	0	6	7	9	0	6	8	—	—	6	9	—
40	0	6	7	9	0	6	7	8	9	6	9	10 ‡

† Turkey Red oil : *For 5 per cent of water.

@ For 10 per cent. of water ‡ No separation.

Note : Tar (1) With 40 per cent. water and 15 per cent portland cement, adhesivity index is 6.

Bitumen (2) With 40 per cent. water and 10 per cent portland cement, adhesivity index is 7.

,, (3) With 40 per cent. water, 10 per cent. portland cement and 4 per cent. Turkey Red oil adhesivity index is 7.

NINTH SESSION-MADRAS-FEBRUARY 1945

STABLE CAUSEWAYS ON UNSTABLE FOUNDATION SOILS

(PAPER No. IX–100)*

DISCUSSION

(Monday, February 12, 1945)

Mr. Modak (Chairman) requested Mr. K. S. Raghavachary to introduce the Paper in the unavoidable absence of Mr. Ahmed Mirza, the Author.

Mr. K. S. Raghavachary congratulated the Author on a paper which, in spite of the contentious nature of the principles enunciated and the conclusions drawn therefrom, would, he hoped, evoke considerable constructive criticism on the design of Causeways, a subject that has not previously received much attention by the Congress.

The main conclusions drawn from the Paper were :—

(i) Causeways or submersible bridges can be founded on erodable soils such as sand, loam or clay, if they have a monolithic base called a "compression raft" by the Author.

(ii) When these are founded upon rock or other inerodable strata, their design does not call for consideration in directions other than those considered for high level bridges.

(iii) The water flowing through the vents has a tendency to form free *vortices* while the water overtopping the structure dissipates its own energy by forming horizontal rollers. In support of this the Author refers to extracts from Dr. Raju's paper.

(iv) In the case of sandy soils met with on the Deccan plateau or in hilly tracts, which are coarse in structure, there is no piping action while in this area the percolation

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*Vol. IX Part 2—pages 55 A to 69 A.

Lecture delivered by Dr. Raju at the third annual session of the Hyderabad centre of the Institution of Engineers (India), on Experimental Investigation regarding the nature of flow in the arched vents of deep submersible bridges during floods.

through clay or loam is never so strong that the soil particles get dislodged. In the Author's opinion piping action may therefore be ignored in the design of foundations of causeways in the Deccan.

2. Taking the last conclusion first, research work elsewhere and accepted practice do not support the contention of the Author. Piping action is possible through all pervious strata. Suitable floor length in conjunction with adequate depths of curtain walls at the end of the flooring are always provided, the actual dimensions depending upon the head causing the seepage flow and the nature of the sub-soil. In his designs, the Author himself has provided flooring and curtain walls and it would have been of advantage if he had given a scientific method for determining the length of his flooring and the depth of his curtain wall.

3. The statement of the Author that the design of the superstructure of a submersible bridge or a causeway does not call for any more consideration than that of a high level bridge does not appear to be correct or based on research. There can be cases in which the magnitude of the horizontal force is not infinitesimal, as the Author suggests, as compared to the weight of the structure and therefore this factor affects the design of piers.

4. The Author stresses the necessity of having "compression raft" foundations. The full significance of this is not clear. He assumes the angle of dispersion of pressure in surkhi-mortar as 49° 25', and assumes for purposes of calculation 45°. This 49°. 25' is based on the assumption that the permissible tensile strength of C.R. stone in surkhi mortar is 20 lbs. per sq. inch. The details of this are given on page 159 of the Indian Concrete Journal for August 1944.

According to this requirement and the contention of the Author that the entire raft without any gaps should act under compression, it would follow that for economic design the spans of all submersible bridges or causeways should be so adjusted as to have one monolithic raft foundation from the beginning to end of abutments and that this raft should be so designed that the pressure on the soil below the raft does not exceed 0.75 to 1 ton. These are all contentious points. It can easily be shown that causeways constructed without a continuous raft in sandy soil and other erodable soils are more economical in particular cases than those built on monolithic bases and are sound in design. Many such have been standing for a long time.

5. On the other hand, structures built to the design of the

Author cannot be said to have stood the test of time, as from the list given by him on page facing 69-A. (VOL. IX-2), it appears that they are mostly from 2 to 5 years old only. It is significant that in no case have any of the structures yet experienced anything like the flood they are said to have been designed for, typical items being No. 1 where the maximum depth of submergence so far has been only 7.5 ft. while the designed submersion is 13.75 ft. and No. 4 where the corresponding figures are 4 ft. and 13.75 ft.

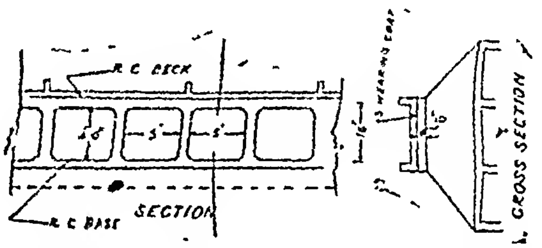
6. One other point that appears to be objectionable in the design is the large amount of obstruction caused and consequent additional heading up or afflux. Minimum obstruction to the flow of water is to be aimed at in all bridge designs, and more particularly in the case of causeways. Also small openings will get easily choked up by brushwood and debris in floods, and the whole causeway will then act as an anicut or dam, causing obstruction to traffic even in low floods.

7. Though the Paper deals in general with the design of causeways over unstable foundation soils and sketches are furnished for various types of vents, such as segmental arches, rectangular openings, etc., the Author has, in the main, confined his calculations to surkhi concrete pipes. Surkhi concrete pipes are cheap, use indigenous materials, and with the simple centring proposed by the Author, do not require expert technical supervision. But this design, because of the limiting size of the pipes, is suitable only in places where the formation level of the causeway does not far exceed the normal summer flow level of a shallow stream.

8. With reference to details, in the calculations of the pipe (arch), it is assumed that the horizontal thrust acts at the centre and is equal to the sum of dead and live loads. These assumptions do not seem to be correct as also the assumption that the spandrel filling in surkhi concrete is considered as a part of arch ring.

9. There is one point which the Author has not touched upon, viz., the relative economy of the design proposed by him, as compared to the normal design with deep piers. In many cases it will be found that the cost of the heavy flooring and the curtain walls outbalances the saving on the cost of piers. In such cases there is no point in adopting a design which causes such severe afflux and obstruction to the water-way.

Mr S. K. Palit observed that in flat deltaic tracts it would be undesirable to have high embanked roads shutting off the free spills of the rivers and channels. In these cases, causeways and submersible bridges with necessary vents were generally constructed. In his opinion, it would be cheaper and more desirable to have causeways composed of a series of R. C. Box Culverts as indicated in the sketch below:



2. The disadvantages of surkhi concrete pipes are:—

(i) Surkhi concrete is easily acted upon by saline water and air.

(ii) It is not often possible to manufacture good bricks and obtain surkhi near the works.

(iii) The inner faces of the surkhi concrete vents are likely to be scoured by the flow of water inside the barrels.

3. The advantages of R. C. Box type structures are:—

(i) Lesser foundation excavation is required for the box type culvert. As there will be consequently less interference by percolation of sub-soil water, it is easier to build.

(ii) Load is uniformly distributed over a greater area. Intensity of pressure is thus reduced to a minimum, thereby avoiding the necessity for elaborate foundations in places where soils are of poor bearing capacity.

(iii) The boxes, as they form a monolithic mass, stand well under water.

(iv) They do not require frequent inspection and repair.

(v) They are easy of construction, not requiring special types of mould or centring.

(vi) They require only thin walls, thereby offering less resistance to flowing water.

(vii) They will not be damaged by flowing water.

4. He considered that the approaches of causeways should be pitched with heavy stone blocks to withstand the force of flood water.

Mr. K. K. Nambiar said that three safeguards must be borne in mind in designing a causeway or submersible bridge:

(i) the decking should be heavy and designed against uplift;

(ii) the hand railing should be of the collapsible type;

(iii) the decking should be suitably anchored to the substructure, provision being made at the same time for lateral expansion and contraction.

2. He quoted the case of a bridge constructed at Panimangalore in South Canara with timber decking. It was opened for traffic in 1916. In 1923 during very heavy floods, some of the central spans were lifted up bodily and carried about 100 yards downstream. That was probably due to the fact that the decking was light.

3. His second suggestion was that the hand railings should be so constructed that they do not form an obstruction to brushwood and floating debris when the flood overtops the causeway. A suitable design of hand railing which would collapse when the floods rise to deck level had been evolved by Rao Bahadur A. Nageswara Ayyar. He thought that the design could be improved as experience was gained in its use.

4. Regarding the third safeguard, namely, anchoring in Madras one arrangement to achieve this is to use holding down bolts to connect the deck to the pier while permitting longitudinal movement of the slab in expansion and contraction.

5. He considered that whenever high velocity was encountered, a high level bridge was to be preferred to a submersible bridge.

Rai Sahib Fateh Chand would prefer cement concrete or even brick in cement to surkhi concrete. Hand railings are essential for safety and the collapsible type would be better. In deciding whether the structure should be a causeway or high level bridge, the criterion should be comparative cost and the nature of traffic over the road.

Mr. T. R. S. Kynnersley recalled that the Conference of Chief Engineers held in Nagpur in December 1943 had permitted the use of submersible bridges or causeways provided the effective submergence at any time did not exceed twelve hours and the frequency was not greater than six times a year. He regarded this as a very generous concession which was to be tak

advantage of only when the adoption of the submersible type structure resulted in considerable savings in first cost.

2. Referring to Raju's laboratory at Hyderabad, he said that when he had personally watched the experiments, he found it very interesting to observe the damage to the sandy bed provided in the model by the movement of water through the ventage channels and over the decking. He would recommend that every one who could possibly do so should visit this laboratory.

3. In his view, surkhi concrete pipes would not generally be suitable for causeway openings, as any but the hardest material would stand indefinitely the abrasive action of suspended sand in the flood water. He would prefer Hume pipes made of dense spun concrete which would effectively resist the abrasive action of sand. He asked whether signs of abrasive action in the lime concrete pipes had been observed in Hyderabad.

Mr. B. N. Shenoy was of the opinion that the foundations of causeways should be taken to incrodable depths, based on the critical scouring velocity for the particular soil met with at the foundation depths. The design of the superstructure should take into account the difference between the ordinary flood level and the high flood level, especially in the case of wide streams, because this affects the period and frequency of submergence.

2. In the case of small streams, there are different methods of reducing the velocity in the vents of causeways. One of these would be to provide sufficient vents in the deep channel portion, and dish the approaches to serve as safety valves in times of high floods. In the case of flush causeways, the approach road level should be at least six inches above ground level to provide for efficient drainage and to keep the roadway clear of slush and silt that would accumulate during floods. In his opinion, it was not necessary to continue the approaches of the causeways very far —short masonry approach walls would do if sufficient protection is provided by revetments.

Mr. W. B. Calder felt that in the discussion that has so far taken place very little had been said about foundations. Irrigation Engineers had considerable experience in this important subject and he would suggest that Road Engineers should draw freely on this experience.

2. It would not be enough to say that a monolithic foundation is required and to leave the dimensions of the pavement and the depth of curtain walls to guess work or rule of thumb. The

subject is a complicated one, and has been fully dealt with by Rai Bahadur Khosla in his paper* on the design of weirs on permeable foundations. For the design of foundations of such causeways as the Author deals with, we need not go beyond what has been already covered by Mr. Khosla in his paper.

3. In the design of these foundations, we have to consider both upthrust on the pavement and scour in the bed downstream. In the case of causeways, this upthrust is due to afflux and is much less than in weirs and regulators in which there is considerable cut off. The upthrust has to be withstood by the weight of the pavement itself, and not by the weight of the superstructure, or roadway.

4. The Author's design of a monolithic foundation provides on flexible downstream bed protection against scour. This is necessary where the flood discharge is substantial. By making the downstream curtain wall sufficiently deep, the risk of damage by undermining can be eliminated, but the depth can be reduced by providing downstream protection such as *Tarungars* or a falling apron of stone.

5. Regarding the type of openings, piers are usually preferable to pipes as they cause less afflux and disturbance. However, where pipes are used, they should be of reinforced concrete, such as Hume pipes.

6. He understood that the usual practice for side protection over causeways was to provide guard stones rather than hand-rails, as no one would attempt to cross a causeway in floods.

Rao Bahadur A. Nageswara Ayyar disagreed with Mr. Calder's contention that hand railings were not very necessary for submersible bridges and causeways. As the traffic would continue to use these structures even up to a submergence of 1.5 ft. above deck level, hand railings were essential and should be provided. Rao Bahadur had evolved, some years ago, a design for automatic collapsible railings for a submersible bridge over one arm of the Godaveri river, and this design had so far worked satisfactorily.

2. The details are as follows:—

> The hand rails of this design, which is suitable only when the spans are small, consist of two horizontal channels spaced 1 ft. 3 in. apart, and rigidly connected by ver-

*Design of Weirs on Permeable Foundations by Rai Bahadur A.N. Khosla. Dr. N.K. Bose and Dr. E. Mackenzie Taylor—Central Board of Irrigation Publication No. 12.

ticals, the length of the frame covering one clear span length. Over the ends of each pier, reinforced concrete cages are constructed, the top being taken well above the maximum flood level. The bottom of the cage is perforated by small openings to admit flood water. The frame is attached by steel wires passing over pulleys fixed on the top of the cages to suitable counter-weights at the other end. These counter-weights consist of concrete blocks and a wood disc with a central hole to admit the steel wire to pass through. The combined weight of the concrete and the wood disc is kept about 1.5 cwts. more than that of the frame so that, with a person sitting over the railing, the frame will not move down. The frame slides in grooves on the outer side of the cages, and the counter-weights slide in the cages. In the normal position, when there is no flood, the bottom of the frame is 1 ft. 3 in. above the deck slab with the counter-weight at the other end of the steel wire resting on the bottom of the cage. The top of the railing is then 2 ft. 6 in. from the road level. When the water rises, it enters the cage, lifting the wooden disc. The concrete counter-weight loses weight by buoyancy, the hand-rail frame becomes heavier, and slowly moves down, raising the counter-weights in the cage. The frame slides down outside the deck slab till the top of the frame is flush with the deck level, when it rests on two cantilevered supports from the cage arresting further downward movement. When water in the stream falls, the reverse action takes place, the wood disc seats itself over the concrete block, the weight lost by buoyancy is regained, and the hand-rail frame is raised to its normal position.

2. In view of the satisfactory results so far obtained by this arrangement, R.B. Nageswara Ayyar felt that the design with suitable improvements and modifications could be generally adopted for submersible bridges in deltaic rivers where there is little danger from floating timber.

3. He cited several cases where causeways had not been found suitable in streams with very high velocities. Even with velocities from 8 to 10 ft. per second, the pavement had been dislocated and from his experience he would not recommend this kind of structure in places where the velocity would exceed 8 ft. per second.

4. Examination of failures of causeway in Madras had

shown that, in most of the cases, the failure was due to shallow foundations, unprotected by heavy aprons. Foundations should be taken to inerodable depths or aprons should be provided. The causeways themselves tend to act as dams, and should be designed as dams. He would prefer a high level bridge to a causeway if the extra cost is not more than 25 to 30 per cent.

5. Regarding surkhi concrete pipes, he doubted whether they would be cheaper than cement concrete pipes, as the thickness of the surkhi concrete would be considerable. There is also the uncertainty of the quality and strength of different surkhi mortars which vary considerably from place to place. In the case of cement there is a guarantee of minimum strength and hence there is consistency everywhere. Further, with lean mixes, cement concrete pipes could be constructed to the same design as surkhi mortar pipes and at the same or even less cost and without the disadvantages of the surkhi mortar pipes.

6. One other factor that should be considered in these designs is the amount of cutting necessary at the approaches. A considerable amount of silt would be accumulated when approaches are in cutting below flood level, making transport difficult and sometimes dangerous even for pedestrians. A low causeway is particularly unsuitable in localities where the river is running between deep banks. If causeways are adopted at all in such localities, the approaches of the river, both upstream and downstream, should be widened for considerable lengths to provide free flow of water across the road approaches, thus avoiding stagnation of water and silting on the approach roads.

Mr. N. V. Modak, the Chairman, in winding up the discussion, said that the Author had done great service to the Indian Roads Congress by writing this paper as it had evoked keen discussion. He felt that sufficiently reliable data for calculating flood discharges of rivers are not available in this country and that it is high time that several gauge stations be set up all over the country for collecting reliable information from gauge readings as had been done in U.S.A. where there are some 80,000 such stations and as is being done in the United Kingdom. It would then be possible correctly to gauge the flood discharges of many Indian rivers. Information about flood discharges, maximum rainfall, etc., would be helpful, not only to the Road Engineers, for the Rs. 450 crore Post-War Road Plan, but also Irrigation and Hydroelectric Engineers, Agricultural Engineers, etc.

The discussion on the paper then concluded.

Mr. K. A. N. Chetty felt that the monolithic foundation suggested by the Author would be a protection against percolation and scour. As a further precaution, he would suggest a line of cut-stone piles 6 ft. deep, for the vented portion on the upstream side. Where interruptions to traffic during floods could be permitted, as in the case of District and Village roads, he would recommend causeways with crest level one foot below the normal flood level. Also, he would prefer rectangular vents to pipes, as the latter afford greater obstruction to the flow, and a greater length of causeway would be necessary to provide the same waterway as in the case of rectangular vents.

Mr. M. Farhatullah said that from his experience after having constructed two of the causeways (items *3 and 7 in *the statement*), the designs suggested by the Author ensured speed in execution, durability, and economy in cost. Local material and labour would be sufficient and high technical supervision would not be necessary as the design is simple and construction easy. Deep foundations are not required, thus avoiding the tedious and troublesome problem of dewatering foundations.

With the large programme of road development contemplated, he stressed the need for standardization of structures similar to those discussed in the paper, to solve economically the problem of very many drainage crossings on comparatively unimportant roads.

Mr. J. T. Metha doubted the adequacy of shallow foundations in the case of segmental arches, indicated in drawing No. 1 of the paper, as in the case of arched openings, the foundations should invariably be taken to unerodable unyielding hard soils. Any slight settlement or movement of the foundations would be disastrous to the entire structure, and he would recommend only rectangular openings with reinforced concrete decking.

Mr. A. S. Adke stressed the importance of evolving standard designs for cheap causeways that would be required in the post-war period for connecting practically every village with the main communication system. The present paper was therefore opportune as it discussed one type of design for such causeways in unstable soil foundations. Where the soil is loose, the stream is usually shallow and wide. In such conditions the bed level would get raised in course of time by the silting action induced by the construction of a causeway. Raising of the vents would then be necessary. Rectangular openings with pre-cast R. C. slabs would easily lend themselves to such raising and should be preferred.

*See next to page 69 A, Vol. IX—2.

In the case of small nullahs, he would prefer a causeway with Hume pipe vents as these could be quickly and cheaply installed. Monolithic foundations of concrete are not necessary. Several Hume pipe culverts had been constructed by him with a concrete bed 1 ft. thick on compacted moorum filling. The side walls at either end of the pipe had been taken below scouring depth with a dry-stone flooring on the downstream side, and these structures had been standing well.

Another objection to adopting the massive monolithic foundation in streams with loose soil was the frequent change in the course of the streams. If a stream is to be confined to the site of the causeway, costly training works would be necessary. Hume pipes, however, could be dismantled and relaid in the new course with little extra cost.

The Author in a written reply to the comments on the Paper apologised for his unavoidable absence from the Session and inability to introduce his Paper personally and expressed his thanks to Mr. K. S. Raghavachary for so ably coming to the rescue and to Mr. N. V. Modak and the Members who took part in the discussion for all that they had done.

Continuing, the Author remarked that he was not aware of any investigation carried out to establish a theory of piping action in coarse and gritty sand or sandy or alluvial soils and for this reason the laboratory experiments mentioned in his Paper were undertaken in Hyderabad. Hydraulic Engineers also had not, as far as the Author was aware, hitherto evolved a theory to determine the manner of formation of horizontal rollers and their intensity and magnitude. But there is no doubt that the phenomenon exists and has been successfully catered for in Irrigation Diversion Works. In the present stage of progress, therefore, Engineers must adapt the empirical rules so far evolved in the light of their personal experience and observation.

The Author doubted whether the horizontal force in the case of any arched submersible bridge could ever be more than infinitesimal as compared with the weight of the structure. He did not claim that the theory he had evolved covered even the specific cases mentioned in his Paper, but he was of the opinion that if the height of a causeway were small, the depth of flood above the causeway would also be small and there would be no danger of serious scouring on the downstream side. He considered that the monolithic base which he advocated was sufficient to take care of any small scour that might occur.

The Author agreed that the structures described in his Paper had not yet stood for any length of time but they had stood sufficiently long to reveal any weak points inherent in the design. He considered that as causeways of the type described by him were seldom more than 6 ft. in height above the average bed levels, the pipe type described would be found generally effective. It appeared sound to treat the spandrel filling as part of arch ring as it was monolithic with the ring.

With regard to Mr. Palit's remarks, the Author called attention to the passages in his Paper wherein it was stated that the designs suited the conditions obtaining in the Deccan plateau and similar areas where the streams were narrow and deep, the floods relatively high, and stone and lime cheap and obtainable in abundance. Mr. Palit's design, on the other hand, appeared suitable for deltaic streams where the bed widths were large and flood heights relatively small.

The Author agreed with Mr. Kynnersley that the sills of surkhi concrete pipes were susceptible to erosion where the river carried coarse sands. At such places special precautions had been taken.

Replying to Mr. Calder the Author drew attention to the fact stated in his Paper that the theory enunciated by him pertained essentially to streams with beds of coarse sands and not to alluvial sands and silts dealt with by Rai Bahadur Khosla in his work. He agreed that valuable conclusions could be drawn from the work done in alluvial rivers but for the conditions considered in his Paper loose stone aprons would not, he thought, be suitable because of the high velocities prevalent and because they would be very expensive to maintain.

The collapsible railing described by Rao Bahadur Nageswar Ayyar was unsuitable for use on the causeways described in the Paper because of the rapid velocity of the streams. For such causeways guard stones appeared all that was necessary. He agreed that cement should be used in place of lime, if more economical. He also agreed that the approaches to causeways should be kept clear of silt but he had not seen any really satisfactory solution to this problem.

The other comments on the Paper did not appear to call for any particular reply. The Author was, however, very grateful for the interest in his Paper evidenced by the comments and to Mr. N. V. Modak for his summing up of the discussion.

NINTH SESSION—MADRAS—FEBRUARY 1945

A DESIGN FOR BULLOCK CART WHEELS

by B. V. Vagh

(PAPER IX—101) *

DISCUSSION

(Wednesday, February 7, 1945)

Mr. F. E. Cormack (Chairman) called on Mr. B. V. Vagh to introduce his Paper.

Mr. B. V. Vagh, the Author, in introducing his Paper for discussion brought out the salient points relating to bullock carts in the following two tables :—

TABLE I

STATISTICAL DATA

TRANSPORT VEHICLES IN INDIA (including STATES)

Item	Motor Lorries	Bullock carts	Proportion of 3 to 2
1	2	3	4
(a) Number.	17,300	87,16,000 (6 per cent. urban) (94 per cent. rural).	500
(b) Capital invested (crores).	6·0 (Rs. 3,500/- per lorry).	261·0 (at Rs. 100 per cart and Rs. 200 for bullocks).	43
(c) Load capacity per trip.	52,000 (at 3 tons each).	45,00,000 (at 0·75 ton for urban carts, at 0·50 ton for rural).	87
(d) Miles travelled per annum (in crores).	69·0 (at 40,000 miles per lorry).	593·0 (at 3,500 miles for urban and 500 miles for rural carts).	8·6

N.B. "Bullock carts handle about the same tonnage of goods as Indian Railways"—J. Vesugar in his paper, "Proposals for an All-India Survey of Bullock Carts by means of Random Sampling" —Paper J—VIIIth I.R.C. Proceedings.

*Published in the I.R.C. Proceedings, Vol. IX—No. 2. pages 55 to 99.

TABLE II

SPOKE-TYPE AND ARM-TYPE WHEELS

(In India including States)

S. No.	Item	Spoke-type wheels 75 per cent.	Arm-type wheels 25 per cent.	Proposed
1	2	3	4	5
(a)	Total number (estimated) in crores.	1·3	0·43	
(b)	Pre-War construction per wheel Rs.	15 to 35.	15 to 35.	17 to 40.
(c)	Pre-War maintenance per wheel Rs.	1·5 to 2·0.	2·3 to 4·0	2 to 3.
(d)	Average life in years.	15 to 20.	(a) 4 to 5 wooden tyre; (b) 10 to 15 steel tyre.	15 to 20.
(e)	Wheel diameter in inches.	42 to 66.	42—60.	60 or less
(f)	Weight of each wheel in lbs.	140 to 260	200 to 275.	Same as at present.
(g)	Intensity of load per inch width of tyre in lbs.	500 to 800.	500 to 800.	250 to 400

N.B. "An urban cart handles about 11 times as much tonnage as a rural cart"—J. Vesugar in his paper "Proposal for an All-India Survey of Bullock Carts by Random Sampling"—Paper E—VIIIth I.R.C. Proceedings.

He proceeded to show from Table I that the bullock carts carried in the pre-war period most of the road transport in this country, and practically the same tonnage of goods as carried by the Railways. In numbers, capital invested, load carried, and miles travelled, carts played a considerably more important part in the country's economy than motor lorries. Though after the war, a rapid increase in the development of motor lorry transport would have to be expected and would displace the bullock carts in due course, Mr. Vagh considered that this would take a long time (more than 20 years), and that in road development plans for the next 20 years, due note of the damaging effect of the existing bullock carts should be taken by road engineers, and every attempt made to reduce this damage by improving the cart design and other means. He also pointed out from Table II that for smaller diameter arm-type wheels, which number about 25 per cent. of the total, the cost of construction is about the same as that of spoke-type wheels, but maintenance is higher and the life shorter. He drew particular attention to the fact that the urban cart handles 11 times as much tonnage per annum as the rural cart, and thus offers an obvious field for conversion to the pneumatic tyred type with roller bearings. The improved type of wheel with broad felloes recommended by him would apply to the rural carts which form 94 per cent. of the total cart population of the country. Carts to the proposed design would cost only 12½ per cent. more than the existing types, in construction, with a little higher maintenance, but the intensity of load transmitted to the road would be reduced to half, thus reducing the damage to the road. The weight of the new wheel is kept the same as that of the existing type by reducing the wheel diameter. The increase in tractive effort on account of such reduction is negligible as the tyre is broadened.

He explained the specimen type designs recommended by him for adoption in various parts of the country according to the load carried (Appendix C, pages 66-67). These designs are meant to cover all variations in present construction, and to conform as closely as possible to standard methods of workmanship usually followed by village wheel-wrights. Modifications should be made, where necessary, to suit local conditions.

Arrangements had been made for making these wheels at different centres and testing them. Two sets made at Madras and Bombay were being tested on the road. The set of wheels made at Madras had done by the end of January 1945 450 miles with a pay load of 1 ton, they were exhibited at the meeting and were found to be in good condition. The Bombay wheels had done 1,200 miles with a pay load of 15 cwts. and were also reported to be in a good condition. Both these sets had been fitted with two steel tyres

$1\frac{1}{4}$ inch by $\frac{1}{2}$ inch with a central wooden portion. Experience to date seemed to indicate, especially over surfaced roads in Bombay, that the central wooden band would continue to remain flush with the two end steel tyres even if initial wear were to take place, by taking up grit, coated mud, etc., from the road surface. Over unsurfaced roads, this effect should be more pronounced. If this is borne out by further experience, the central steel band may not be necessary to protect the wooden portion. One of the 6 sets of wheels now under test has this central steel band, and its performance will be watched. He felt, however, that the broad felloe will check wobbling which alone would cause steel bands to cut the road surface and damage it. Experience to date has shewn that this does not happen. The three main items causing damage to the road are the intensity of load, the cutting edge of the tyre, and wheel wobble, and all these are minimised by the provision of a broad felloe.

He expressed satisfaction at the interest taken by Provinces and States who are now coming forward to manufacture wheels to the new designs and test them. Any modifications necessary to suit local conditions would then be known.

He suggested that accelerated tests should be undertaken on the Road Test Track at Alipore, Calcutta, on both the types, to see the comparative life of the two designs, and the need or otherwise of a central steel band.

He finally referred to the psychological reactions of cartmen to any deviations from the age-long accepted design of the cart wheels, in spite of the minimum changes now proposed. He would seek the active assistance from the Provincial Governments, States and Municipalities to popularise the new designs by manufacturing a large number of such wheels (at least 100 pairs) and proving by their actual performance their superiority over the existing ones. He felt gratified that Mr. Modak, Bombay City Engineer, would persuade his Corporation to convert wheels of 12 carts to the new design, and that representatives from Bhavnagar and Baroda had agreed to do likewise.

Mr. W. B. Calder congratulated the Author on a most useful and practical paper. The bullock-cart problem varied from Province to Province. Untyred wheels would be suitable for unsurfaced roads, and any improvement of this type should be made without introducing the steel tyre. Surfaced roads would, however, require steel tyred wheels. The main defects in this type at present are the narrow tyre and the inefficient

hub which allows the wheel to wobble. The Author's adherence to the existing design and materials, as far as possible, would commend itself to every one. Though the proposed width of 5 inches for the rim would appear suitable for the carts dealt with by the Author, he would consider a 4-inch width sufficient for lighter loads. The ordinary cart in Sind, for example, is fairly similar to the Bombay type, but its weight is about 492 lbs. and it carries 12 cwts. or over 16 cwts. total. With the improvements contemplated, the load could easily be increased to nearly 15 cwts. making a total of 19 cwts. With 4-inch tyres, the load per inch width would be 266 lbs. against 300 lb. for the Author's 5-inch wheel on the Bombay cart.

He felt doubtful about the advantage of using two narrow end bands to reduce the weight of the wheel. The unprotected central wooden felloe must wear in a short time, when the full load will have to be taken by the two narrow tyres, increasing the load intensity per inch width from 300 lbs. to 600 lbs. The only effect would be to reduce the tendency to wobble due to the wider rim. He deprecated the use of a thinner central band to protect the felloe, as cumbersome, and costly, and preferred a full width steel tyre 4 inches or 5 inches.

The Author's over-emphasis on keeping the weight of the improved wheel the same as that of the existing wheel appeared to him to be unnecessary. As indicated by Professor Taraporewala, the tractive resistance of a broad rimmed wheel is less than that of a narrow wheel, and any small increase in the weight of the cart will be more than counterbalanced by the lower tractive effort. Any improvement in the bearing will further reduce this tractive effort.

In Mr. Calder's view, wobbling is one of the main contributory causes of road damage, perhaps causing more damage even than narrow tyres. To ignore the improvement of the bearings would leave the job half done. Professor Taraporewala had pointed out that rigidly fixed wheels without springs will tend to wear out the road faster only if the surface is already rough. As a better bearing will lengthen the life of thousands of miles of good and expensive roads, improvement of the bearings should be effected as early as possible. He considered roller bearings to be ideal, provided these could be produced at a reasonable price in this country after the war.

The design proposed for the pneumatic tyred wheel by

the Author could be adopted but he would suggest a special design of more rugged construction which would be cheaper and more suitable. This type of bearing which he intended to try out himself in Sind, is a modification of that used in the Cumming wheel and consists of a cast iron bush fitted inside a 3-inch diameter W. I. pipe and fitted with a grease cup for lubrication. This type could be easily and cheaply made in a small workshop.

Referring to the Cumming wheel, Mr. Calder stated that four points of criticism raised against it were :—

(a) its type of construction;

(b) weight;

(c) small diameter; and

(d) light rim.

He considered that the first objection that it could not be made by the village wheel-wright was a legitimate one and for this reason it could not have a general appeal. But the other objections are not borne out by facts. The weight of the wheel is only 145 lbs. against 168 lbs. for the ordinary 4 ft. diameter wheels used in Sind, and 179 lbs. for the wheel of design (b) of the Author. Also, the Cumming wheel has a diameter of 3 ft. 6 in. with improved bearing, against a diameter of 3 ft. of the Author's design with roller bearings. The Cumming wheel is mainly intended for earth roads and as such a ¼ inch rim thickness should be adequate; For surfaced roads he would recommend for the rim somewhat lighter angles riveted on to a steel tyre which could be replaced easily. A novel feature of the Cumming cart is that it employs 2 stub axles instead of a single axle. This has the advantage of saving steel in the axle and allowing them to be turned more easily, but they have to be fitted to cross members to ensure exact alignment.

The Cumming wheel was designed as an integral part of the cart which has a steel frame with babul wood bottom and sides and corrugated iron ends. He considered that this type had not so far achieved popularity due partly to several inherent defects and partly to non-availability of steel during the war. One further defect that had come to his notice was that the cart, becomes very hot in summer owing to its steel construction. The cart as a whole, not the wheel, is rather heavy but on a reasonably good surface the improved bearings more than compensate for the extra weight. He added that the Cumming wheel due to its inherent composite construction could not replace the wheel of the existing type.

The type of wheel commonly used in Sind is a spoke type with a diameter of 4 ft. and a hub of 12 inches diameter and 11 inches wide with a plain cylindrical iron bearing. The spokes are 3 inch by 3½-inch, and the felloe 3½ inches to 4 inches deep and 3 inches wide. The steel tyre is 2½ inches wide and ⅜ inch thick. The wood used is babul throughout.

Mr. Calder was intending to improve this wheel by widening the felloe and tyre to 4 inches or 5 inches, fitting a modified bearing of the Cumming type, and reducing the diameter from 3 ft. 9 inches to 3 ft. 6 inches, and testing these wheels on roads.

The following table gives the weights of the wheels of different types proposed by Mr. Calder and the Author : —

Type of wheel	Weight (in lbs.) of wheel with a diameter of		
	48 inches	45 inches	42 inches
Sind type, 2½ in. tyre	168	—	—
Modified 4 in. tyre	210	—	—
-do- 5 in. tyre	243	—	—
Improved hub, 4 in. tyre	218	206	195
-do- 5 in. tyre	251	238	224
Cumming type	—	—	145
Vagh type	—	201	—

He agreed with the Author that the fitting of wheels with pneumatic tyres would be a sound investment for all professional cartmen not only in the urban but rural areas also.

He, however, did not agree with the Author that the cost of conversion of wheels or the supply of iron tyres should be charged to the Road Plan. All classes of road users should contribute towards the cost of roads. Motor vehicle owners and operators are heavily taxed for their use of the roads. Agricultural carts make indirect contribution towards the upkeep of roads through local cess, but professional cartmen pay nothing at all. He considered that it would be reasonable to ask the professional cartmen to effect the improvements suggested for the wheels to reduce the damage done to the roads which are being improved at very great cost to the other sections of the community. Improved road surfaces mean increased pay loads and saving in time and maintenance to cartmen. This should far outweigh the slight increase in recurring cost due to improved wheels and there should be no need even to increase the cartage rates.

Rao Bahadur A. Nageswara Ayyar considered the present time was opportune to introduce improvements in the bullock cart wheel, as due to non-availability of steel during the war, very few carts had been made and existing carts due for renewal could not be repaired. As the conversion of all agricultural carts, which form nearly 80 per cent. of the total, to pneumatic tyred vehicles would be impracticable and economically unnecessary, suitable alterations in the existing design should be effected to reduce the damage to roads. It would pay the road authorities to subsidise the manufacture of the wheels to a small extent by supplying wheels at the existing cost so that all new construction might be of the improved type.

In his view the main defect in the existing design is the rigid hub and axle which do not provide for the adjustment of the wheels to suit the variations in the road surface, with the result that one edge of the wheel rim alone comes in contact with the road with consequent enormous increase in pressure intensity. On account of this defect, the unlubricated bushes wear out quickly, and cause wobble which enables the wheels to adjust themselves to the irregularities in the road surface. But the wobble induces considerable impact and several indeterminate forces tending to destroy the road. An increase in the width of the felloe alone will not be sufficient. Any improvement should aim at the wheels automatically taking a position normal to the road surface with the full width of the felloe in contact with it. In addition, the felloe should also be widened to reduce the intensity of pressure.

He considered that a reduction in the diameter of wheel is not desirable as it increases the tractive effort. Larger diameter wheels get over projecting obstructions with less effort, and present a larger area of contact on flexible pavements, thus reducing the intensity of pressure on the road surface. For economical traction the centre of the wheel should, as nearly as possible, be at the height of the necks of the bullocks to ensure minimum loss of effort by inclined pull.

With these considerations in view, he had suggested two designs (Plates IX and X on pages 69-70). The diameter of the wheel is kept as 5 ft. in both cases. The rims are of special channel section 3·5 inches by 2 inches by 0·375 inch with or without wooden felloes. The spokes can be fitted to channel shaped rim by bolts, and hard wood wedges driven between the rim and the spoke to secure tightness and rigidity. The channel has a moment of inertia of 0·91 inch on the axis parallel to the web and this would be sufficient for the wheel loads till the thickness is reduced to 0.187 inches.

The spokes are twelve in number and of teakwood of section 5 inch by 2 inch.

In the first design, the special features are:—

(a) Cast steel hubs fitted to the wheels as shown in Plate IX, with provision for holding and circulating lubricating oil while the cart is in motion;

(b) Two-piece steel axles 1.75 inches square and 2 ft. 6 inches long. One end of each of the axle pieces is turned in a lathe so as to have a smooth run in the axle box. The other end is bent, as shown in the plan (Plate IX), and fitted to the body of the cart;

(c) The axle is connected to the body by two bolts 0.75 inch diameter with strong spring washers under the axle and a strong helical spring with a play of 0.375 inches above it.

The two-piece axle will permit the wheels independently to adjust themselves perpendicular to the road surface. The increased width of felloe will bring down the pressure to 500 lbs. per inch width.

In the second design, the special features are:

(a) Wooden hubs as in existing wheels

(b) One-piece steel axles 1.75 inches square, with the ends also square and let in sphercial bulb cast bearings with square holes, on either side of the wheel as shown in Plate X.

This will be similar to the kind of roller bearing in motor cars with flexible tyres.

(c) Spherical segment bearings fitted to the wheels so that the wheels may rotate over the bearings and be able to slant within limits in any direction.

(d) Horizontal steel keys fitted in the axle on both sides of the wheel to keep them moving parallel to the axis of the cart.

Details showing the comparative weights and costs of the existing wheels (Madras type) and of wheels to the two proposed designs were given by him (Table on page 58).

He preferred the second type (Plate X) in spite of the slightly heavier cost, as this type corresponded very nearly to the existing

type, with an action akin to that of the existing wobbling wheels but without their bad effect on the road.

He recommended that both the types should be made and tested. With some experience it would be possible to reduce the weight and cost of the wheels. He suggested that a channel 4 inches wide could be used for experiments if the 3.5 inch wide channel is not now available.

Table showing the quantities and cost of *existing wheels* (Madras type) and of the two alternative designs proposed by Rao Bahadur A. Nageswara Ayyar.

(The quantities and cost are for two wheels)

Items	Existing wheel (Madras type)		Design I Plate IX, Separate axles		Design II Plate X, continuous axle with spherical bearing	
	Qty.	Cost Rs.	Qty.	Cost Rs.	Qty.	Cost Rs.
Steel in lbs. (at 0-4-0 a lb.)	222	56	402	101	480	120
Timber in. lbs. @ Rs. 7 a cu. ft. for spokes, and Rs. 10 cu. ft. for felloe.	325	70	164	32	194	39
Bolts and nuts.	10	4	20	20	16	12
Labour.		15		12		15
Sundries.		5		5		4
Total weight (lbs.)	557 or 560		586 or 590		690	
Total cost Rs.		150		170		190

Mr. A. Narayana said that before the design was finalized, further experiments should be carried out on different roads and soils, as conditions vary a great deal from province to province and he would recommend the distribution of 500 to 1,000 pairs of wheels, made to Author's design, to professional cartmen for being tested on roads for a period of 3 months, careful records being kept of the performance of these wheels under the loads carried and of the condition of roads. Side by side with the improvements to wheels, sandy and unmetalled portions in unbridged nullahs should also be improved.

Mr. K. K. Nambiar stressed the urgent need of improving bullock carts to reduce the damage done by them to roads, especially during consolidation of waterbound macadam when the surface is not capable of bearing heavy intensities of pressure. Popularising of pneumatic tyres should also be taken side by side, wherever possible, especially in urban areas. In Madras city where the carts are taxed, the taxes for carts with a tyre witdh of 3 inches and more have been reduced at his suggestion, to 50 per cent. of the taxes payable by carts of lesser tyre widths. Such discrimination would be an incentive for the adoption of a wider tyre, and the change over to the design suggested by the Author. Rural carts should also be tackled in a similar way. At present rural carts do not pay any tax for using the roads.

Rai Sahib Fateh Chand observed that village carts numbering 90 per cent. of the total did little or no damage to roads and that 90 per cent. of the damage is caused by the 10 per cent. urban carts carrying heavy loads. Any plans for the improvement to the carts should therefore be first concentrated on the urban areas. The improved design for bullock carts should be simple and cheap. He would recommend a 4-inch steel tyre. Segregation of bullock cart traffic by providing separate trackways, wherever possible and necessary, would go a long way to solve the problem.

Mr. B. N. Shenoy felt that for village roads which are mostly earth roads, no improvement in the present wheel design would be necessary, damage to waterbound macadam is caused by abrasion of steel tyres and this will not be reduced by the proposed design as the steel tyre does not cover *the full width of the broad rim*. In his view, big corporations like Madras should manufacture a large number of wheels (say 200) to the proposed design, and use them for carts in the Corporation, keeping accurate record of the performance of these wheels. The results should be reviewed by a small

Sub-committee, as to the effect of these partly shod broad tyres on water-bound macadam.

Mr. C. L. Berg questioned the usefulness of the central wooden portion in the felloe of the Author's design. He felt that the time and energy spent in attempts to improve the cart wheel did not justify the results obtained, and doubted whether any improvement in the design could be made for universal adoption throughout India. Rather than attempting to improve the carts, he was of the opinion that it would be better to try to drive the professional bullock cart, which causes the most damage, off the roads altogether. This would be accomplished if it were made uneconomical for them to work. Lorry transport should be encouraged by offering cheap commercial petrol for their use, as is done in England, and by reducing the tax on transport lorries.

Mr. R. N. Padhe considered that the proposed design would not be suitable for rural carts, though they might be suitable in urban areas. Most villages cannot afford more than about Rs. 100 to Rs. 150 a cart, and a cheap design should be evolved.

Mr. H. E. Ormerod suggested that the change over to pneumatic tyres which he considered ideal should be brought about by taxing the existing steel-tyred bullock carts. Alternatively, separate tracks should be provided for steel-tyred carts, instead of trying to improve them. This would allow for necessary segregation, provide improved surface for fast motor traffic, and reduce accidents.

Mr. C. G. Kale observed that due to the camber in the road, the full width of the tyre does not come in contact with the road surface. This condition will be accentuated by increasing the tyre width. With a normal camber of 1 in 24 to 30 for water-bound macadam roads, the difference in levels in a 5-inch rim width will be 1/5 in. to $\frac{1}{6}$ in. Instead of flat tyres he suggested conical tyres with an angle corresponding to the angle of the road. Village cartmen would find it difficult to adopt the two-steel tyred wheel in place of that in present construction.

Rao Bahadur A. Lakshminarayana Rao felt that there would be considerable difficulty to refix one steel tyre, when it gets loose, as, at the time of fixing, the other type would be strained to a considerable extent, and would in turn get loose. In actual practice the design would give much trouble. Till the wheels are tested on second class roads with loose stones on the surface, it could not be said that the proposed design would be an improvement. The heavy wheels could not also be handled easily by cartmen when by an accident these come off the axles. He

considered that the best method of reducing the intensity of load transmitted to the surface, would be by adopting pneumatic tyres. With the price of wood soaring high and the probability of obtaining pneumatic tyres at a price no higher than pre-war prices, it would be preferable to go in for pneumatic tyres which would give better performance and carry more pay loads.

Mr. T. R. S. Kynnersley said that it was proposed to spend some 450 crores on an improved road system and yet the authorities appeared content to continue to allow steel tyred carts to break up the surface of India's roads. Instead of trying to modify or change the existing wheels he felt convinced that it would pay all Governments and States to subsidize the professional cartmen and insist on pneumatic tyred wheels being used on all carts using the modern surface roads. If they refuse they must be heavily penalized by being taxed or forced to use segregated or separate tracks.

Mr. A. J. Diwangara also agreed with the previous two speakers, especially from his experience of the damage caused by steel tyred bullock carts to roads near factories. Simultaneously with the encouragement of pneumatic tyres the existing wheel should also be improved.

Mr. G. M. McKelvie congratulated the Author on the trouble he had taken in preparing his data on bullock cart wheels, and proposing suitable improvements in their design. Bullock carts will stay in the country for a long time even in urban areas, and ways and means of improving them to carry higher pay loads while decreasing damage to the roads and lessening the tractive effort of the bullocks have to be found. Village carts do very little damage to roads, as they mostly carry produce from the thrashing floors to the villages or to the nearest dealer and carry much lower load than professional carts. Any improvement must therefore be first concentrated on urban carts.

He welcomed the proposals of Rao Bahadur Nageswara Ayyar which would eliminate the cutting of roads by tyre edge. He suggested that all the designs should be given extensive trials in the Provinces and States.

Mr. B. V. Vagh, the Author, replying to the comments of Members said that he would group his remarks under the following headings :—

(i) **Suitability of the proposed design for urban and rural carts for varying conditions in different areas.**

To meet these varying conditions, he had evolved four type designs (Appendix C) which give in broad outline the details of construction to be adopted

for varying weights of wheel and diameters. Any modification necessary to meet local conditions should be carried out, and the results of the tests communicated to the Bullock Cart Committee.

(ii) Wear on the central wooden portion of the tyre.

Experience to date had shown that the central portion remained flush with the two-end tyres by picking up road grit. Whether further tests would confirm this experience would probably depend on the quality of wood used, the type of road surface, and possibly on the mileage covered. Further data would be collected. If the central portion did not remain flush, he felt that unless it was found feasible to maintain it economically with some sort of pre-treatment, the only alternative would be steel. The various proposals suggested would be given a fair trial before any design was finalized.

(iii) Improved bearings.

A cheap design that can be easily manufactured by a village wheel-wright is being considered and any suggestions on this point will be welcomed by the Bullock Cart Committee.

(iv) Adjustment of the wheel to the camber of the road.

The two proposals of Rao Bahadur A. Nageswara Ayyar (Plates IX and X) to secure normal contact of the tyre with road for the full width of the tyre by special axle and hub arrangements will also be tried. He, however, doubted whether, in spite of special arrangements, any rigid tyre can fully contact the road surface. In his view this contact will be at several points. Mr. Kale's suggestion to slightly camber the wheel to the cross slope of the road, appeared to the Author to be more practicable and feasible if there is no slackness in the bearing of the wheel and if the wheels are not interchanged.

(v) Provision of separate tracks for carts.

Mr. Vagh considered that separate carriage ways might be necessary if the volume of traffic warrants this. If the number of carts on a road is so large as to restrict fast moving traffic, a separate carriageway will be required even if all the vehicles had pneumatic tyres. Separate carriageways for steel tyres would be justified if the

cost of providing and maintaining them was less than that of improving the wheels. He did not consider this possible as by improving the wheels maintenance charges on existing roads are saved, while by providing separate tracks more expenditure is incurred on const.uction and the maintenance charges are increased.

(vi) **Displacing the Bullock Cart and or Taxing it.**

It would not be possible to displace the bullock cart for a long time to come as the bullocks are required for agricultural purposes and could be used in the off season for transport. The suggestion to displace the bullock cart by subsidizing motor transport could not, even if feasible on practical grounds, solve the problem since the taxpayer still have to pay. The taxpayer's burden would be reduced only by saving maintenance on his roads.

He was inclined to the view that, except the professional carts, the large number of other carts should not be taxed as they would not have sufficient work to earn enough for the sustenance of their bullock and the driver. He would, however, accept Mr. Nambiar's suggestion for differential treatment of taxation in urban areas.

(vii) **Pneumatic tyres versus Broad rim tyres.**

He agreed with the speakers who said that pneumatic tyres, would be the best solution, but till a total conversion was effected, which would not be for a long time to come, the first step would be to improve the carts by providing broad rim tyres without disturbing the cart industry or adding materially to the cost of the wheels.

(viii) **Miscellaneous :**

(a) The new design makes no material change in the present wheel, except for the substitution of a wider felloe and can, therefore, be adopted in any cart.

(b) The weight of the new wheel will be the same as in the present construction and hence its handling will not cause any extra trouble.

(c) He did not anticipate any trouble in fixing the steel tyres when one of them got loose. So long as both the tyres are of the same diameter, and are heated to the same temperature their contraction

and the consequent pressure exerted by them will be the same. If one of the tyres gets loose, it should not be cut but only re-heated for re-fixing. This operation would make no difference in the shrinkage stresses.

Mr. Vagh concluded his remarks by requesting as many members as possible to manufacture a large number of wheels, carry out experiments, and report the results of their tests to the Bullock Cart Committee.

Mr. F. E. Cormack (Chairman) in summing up the discussion said that he was of the opinion that it was essential that extensive trials should be made to improve the bullock cart wheel. If the pneumatic tyres could be made cheap for the ordinary cartman, the problem of the bullock carts would not arise, but this was not likely to happen. Segregation of traffic would not also always be possible. The bullock cart would stay for many years to come. Mr. Vagh had, therefore, done a very valuable piece of work by carrying out experiments on the improvement of the present cart wheel. He had spent a great deal of time and taken a great deal of trouble in producing his paper. Mr. Cormack finally urged all the Chief Engineers of Provinces and States and other members to bring all the pressure they could to bear on their administrations to manufacture as many pairs of wheels of different designs and to experiment on these wheels. He agreed to do this in his province (Assam).

The discussion then concluded.

CORRESPONDENCE ON "A DESIGN FOR BULLOCK CART WHEELS"

Mr. K. A. N. Chetty in his comments received by correspondence stated that even after completing the network of village roads in the next 10 years according to the Nagpur Plan, thousands of carts from the interior regions would trek across the hilly slopes, terraced lands, and difficult country and would then continue their journey on roads with improved surfaces. A broad rim wheel would not suit these varying conditions. He was also doubtful whether the broad rim tyre would fare better than the present tyre on a black top surface.

He felt that with improved roads the present country carts would not be a menace and the real problem was to improve the

roads. Instead of spending money on wholesale conversion of cart wheels he considered that the conversion was necessary only in respect of urban cart wheels to pneumatic tyres and that this should not be difficult as these are either owned or financed by capitalists. Finally, he felt that a few dozen carts made to the Author's design should be tested in the interior regions through the agency of farmers, as conclusions based on such trials would be far more practical than any arrived at by surmise at present.

(The Author has made no reply to these written comments as the points raised therein have been covered in the Author's reply to the comments of members who took part in the discussion—Editor.

APPENDIX C

TYPE DESIGN FOR BULLOCK-CART WHEEL

LEGEND

PARTICULARS		Type A	Type B	Type C	Type D
		INCHES			
Depth of Felloe	a	4	$4\frac{1}{2}$	5	$5\frac{1}{2}$
Width of Felloe	c	4	$4\frac{1}{2}$	5	$5\frac{1}{2}$
M. S. Tyres	2 Nos.	$c/4$ x $1/2''$			
M. S. Band	1 No.	$c/2$ x $3/16''$			
Spoke near felloe	$b \times d$	$1\frac{1}{2} \times 2\frac{1}{2}$	$1\frac{1}{2} \times 3$	$2 \times 3\frac{1}{2}$	2×4
Spoke near hub	$b \times c$	$1\frac{1}{2} \times 3$	$1\frac{1}{2} \times 3\frac{1}{2}$	2×4	$2 \times 4\frac{1}{2}$
M. S. Rings round hub	f	$1\frac{1}{8} \times \frac{7}{8}$	$1\frac{1}{8} \times \frac{7}{8}$	$1\frac{1}{8} \times \frac{3}{8}$	$1\frac{1}{8} \times \frac{7}{8}$
Other Dimensions	g	$1\frac{3}{8}$	$1\frac{3}{8}$	$2\frac{1}{8}$	$2\frac{1}{8}$
	h	1	1	$1\frac{1}{2}$	$1\frac{1}{2}$
Half Diameter of hub	i	$5\frac{1}{4}$	$5\frac{1}{4}$	$6\frac{1}{4}$	$6\frac{1}{4}$
	$n, l, l.$	According to Diameter			

NOTE ON TYPE DESIGN

1. Choose one of the four Tyres shewn in the drawing which for the weight of a new wheel in present construction will have *as wide a rim as possible* with a reduction in the diameter if necessary from 10 to 15 per cent. where the present diameter is above 4 ft.

2. Where the diameter in present construction is below 4 ft. reduce it to 3 ft. 3 in. if necessary and also increase the weight of wheel by upto 10 per cent. if necessary to obtain a Type with *as wide a rim as possible*.

3. The Design is for use on all types of wheels whether they employ a steel tyre or not in present construction.

4. Wherever existing spokes can be fitted in the diameter as per 1 and 2 *without* exceeding their length they may be employed in the proposed design with or without staggered housing according to current practice and with the present hub.

5. Where the spokes and hub shown in the drawing are employed with staggered housing for spokes the hub should be altered as shewn by dotted lines in the drawing to provide space for such housing.

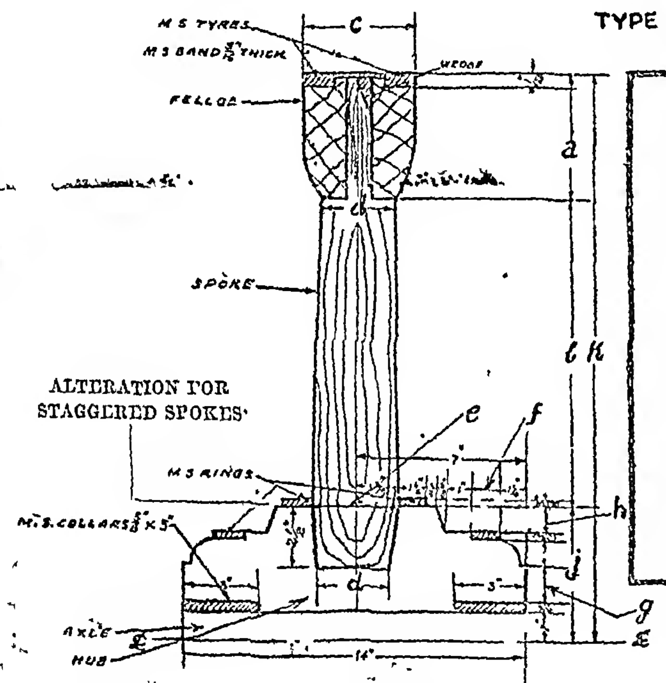
6. In place of the three steel tyres shown on the drawing one tyre $\frac{3}{8}$in. thick may be used over the full width of the rim, either in one or two sections according to convenience.

7. Alternatively the central steel band shewn in the drawing may be omitted and the wooden portion of the rim be made flush with the two steel tyres.

PLATE VIII

BULLOCK CART WHEEL

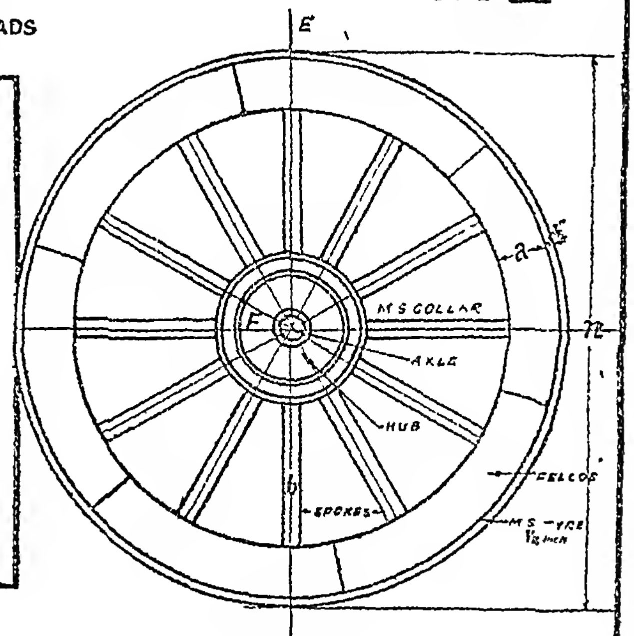
TYPE DESIGNS FOR VARIOUS LOADS



CROSS SECTION AT EF

FOR LEGEND

See Page 66



ELEVATION

I.R.C. PAPER No IX-101-1945

B.V. VAGH

Corrigendum on Paper No. 101 (Pages 55 to 99, Vol. IX—Part 2).

Page	Para	Line	For	Read
63	21	1	Depth of the felloe $\frac{1}{8}$ in.	Depth of the felloe by $\frac{1}{8}$ inch
63	21	4	Table I	Table I, Col. 3 & 4
63	21	5	Item 6	Item 6
63	24	5	Rs. 2/13/-	Rs. 2/12/-
63	24	5	{Table II b (2)}	{(Table II b (ii)}
64	27	9	$2\frac{1}{2}$ in.	$\frac{1}{2}$in.
66	34	Sub-Title	(b) A-Type wheel	(c)A-type wheel
67	35	5	tracking	tractive
67	39	4	Fig. 4	Fig. 4, Plate III,
68	39	2	S-design discussed earlier	S-design for this wheel shown in Fig. 2 Plate IV
68	4	Sub-Title	(c) T-section	(d) T-section
69	42	do	(d) Alternative designs	(e) Alternative designs
69	43	do	(e) Structural stability	(f) Structural stability
75	60	Last line	large scale production	large scale production but allowing 50 per cent. increase on the broad tyre wheel suggested for rural carts.
76	62	7	(para 50)	(para 51)
79	68(ii)	5	one crore	one crore, based on steel tyres *vide* para 64

Page	Table	Col.	Line	For	Read
80	Table I	2	2	6.25	6.5
80	do	2	16	4'-3¾"	4'—4¾"
80	do	3	8	10.5	14
80	do	3	9	—	10.5
80	do	5	last line	4-0-0	8-0-0
98	Table	2	c	4582	2290
98	do	2	d	6454	3220

AJOY BRIDGE—FAILURE OF MASONRY PIERS—REMEDIAL MEASURES ADOPTED

(PAPER NO. IX.—102)*

DISCUSSION

(TUESDAY, FEBRUARY 13, 1945.)

Mr. L.A. Freak (Chairman) requested Mr. K. S. Raghavachary to introduce the Paper in the unavoidable absence of Mr. H. K. Nivas, the Author.

Mr. K. S. Raghavachary, on introducing the Paper for discussion, said that when it was first submitted to the Council he had, in his capacity as Editor, requested the Author to cover at least the following points at the time of introducing the Paper:—

(i) Reasons for selecting the present site of the bridge at a bend of the river (not quite usual). Was this siting obligatory from traffic or topographical considerations, or was no other suitable place above or below the present site, on a straight reach of the river feasible without a long detour ? A plan showing the course of the river for at least two miles above and below the bridge site, and also showing the road system in the area would be very helpful.

(ii) (a) Stress calculations of the piers which failed to elucidate whether the failure was due to shear or over-turning or other causes.

(b) structural calculations for the R. C. columns subsequently provided.

(iii) The remedial measures that the Author considered should have been taken to counteract the effect of the bad siting of the bridge at a bend, and the measures actually taken after the failure to make the regimen of the river stable with the current flowing parallel to the axis of the bridge.

The Author replied that owing to his preoccupation with very urgent work, it would not be possible for him to present the

*Published in I.R.C. Proceedings Vol. IX—2, pages 101 to 104.

Paper in as full a form as he would have liked and he asked the indulgence of Members for what he admitted was an incomplete presentation of the case.

The Author's excuse for referring to the matter of bridge failures at all was that he felt that the subject had in the past not received the attention it deserved. Scientific progress had always been built on failures. If failures of road structures in the past had more often been analysed and the information obtained made available to road engineers, many other failures could have been avoided. He cited as an instance the failure of the Gambhir Bridge in the Punjab some years back, a failure that was similar to that of the Ajoy Bridge. Had information regarding the Punjab failure been available to the designer of the Ajoy Bridge, he would have designed differently. The Author urged that some central organization like the office of the Consulting Engineer (Roads) or the Indian Roads Congress should undertake the duty of collecting information on failures of bridges and the remedial measures adopted, and making it available to all engineers. With the large bridge programme contemplated in the post-war period it was more than ever necessary that such information should be collected and disseminated so as to avoid uneconomic and unsafe designs.

The Author attempted to set up in Bihar a Central Bridging Museum in which would be recorded the history of all major bridges in the Province and information about all failures, their causes, and the remedial measures adopted. He hoped that similar organizations would be set up in the Provinces and at the Centre as these would be of considerable help to all bridge engineers.

Regarding the bad siting of the Ajoy Bridge, the Author explained that a better site in a straight reach of the river was available a few miles upstream but the extra cost both of construction and maintenance of the additional road mileage which would have been involved did not justify the selection of this site. No training works had, however, been provided to neutralize the unfavourable conditions at the site selected because the designer had consid[illegible]fficient protection would be afforded by the surface rock met with at the outer side of the bend.

When the piers were re-designed after failure, provision was made in the new design of the twin R. C. columns for the side thrust forces of the current, and stays were also provided at their bottom and centre. Dicken's formula with a co-efficient of 900 was adopted for calculating the discharge.

The Author desired that members should keep these facts in mind while discussing the paper.

Commenting on the paper, *Mr. K. S Raghavachary* said that at the meeting of the Council of the Indian Roads Congress held at Lucknow in September 1944, Mr. Nivas mentioned several cases of bridge failures due to faulty design of abutments and piers and, at the request of the Council, agreed to contribute a Paper for the Congress. The present Paper was the result.

Though it was the intention of the Council that the Paper should deal with the more common aspects of bridge failures in this country, the Author, due to his other preoccupations, had confined himself to the failure of one particular bridge in Bihar with special reference to its bad siting in a bend of the river which, in the Author's opinion, was responsible for the failure of some of the piers and abutments even before the superstructure had been erected. It was unfortunate that the Author had not been able to furnish calculations of the stresses developed in the piers at the time of failure.

Turning to a point of detail, Mr. Raghavachary observed that the Author claimed that even if the superstructure, had been constructed over the piers before the floods of 1942, the failure of the piers would not have been prevented. This statement, Mr. Raghavachary considered, would not be easily accepted by many engineers and required further clarification by means of structural calculations. The superstructure over the piers would certainly have had a stabilizing effect and would probably have prevented their collapse had they been completed before the floods. The old design which had failed consisted of separate units with thin and thick piers. If all the piers had been of a uniformly thick section, the failure might have been avoided and the extra cost would not have been considerable. If, on the other hand, for economy, thin piers had been accepted, other remedial measures should have been taken in good time.

Mr. S. K. Palit observed that a site plan showing the road alignment and the course of the river upstream and downstream of the bridge would have helped Members to get a better appreciation of the bad siting referred to by the Author. Full hydraulic data collected and used in the design also had not been furnished. The difference in the flow levels at opposite banks of the stream in a bend of the river should have been anticipated and adequate provision made in the design for the effect of the turbulent water caused by the variation in the levels of the flow. The special advantage of adopting spans varying from 37 ft. 8 in. to 61 ft.

8 in. was not also understood. In Mr. Palit's view, economy could have been effected by the adoption of equal spans with alternative spans overhanging and suspended with flexible expansion joints in between (GERBER System).

He did not agree with the Author that the superstructure had no stabilizing effect on the piers. As roughly worked out by Mr. Palit from the drawings, the weight of the superstructure was about 200 tons, while the weights of the thick and thin piers were 100 and 65 tons, respectively. The total superimposed load over the thin piers would have been 265 tons against 100 tons of the thick unloaded intermediate piers, which did not fail. In his view, the thin piers failed because of the tensile stresses caused by the surging effect of the moving water. A superimposed load of three times the weight of the pier would have prevented any tension in the structure and consequent failure of the piers at the base.

The shape of the cutwater had also not been clearly indicated, but Mr. Palit felt that where flow is at an angle to a bridge, circular cutwaters could be adopted with advantage. He also did not like the final design of the twin R. C. piers as these provided room for lodgement of branches of big floating trees during floods, especially in this case where the direction of flow was not parallel to the trestle line. If detailed calculations had been given for the present design adopted for the piers, it would have been of very great advantage to all the Members.

He, however, welcomed this Paper as failures when properly studied are the pillars of success and the lessons learnt from the present case would be of immense value to bridge designers in general.

MR. V. S. Annaswamy gave his experience of training river courses by constructing low groynes, which deflected the direction of flow and brought it as nearly as possible into line with the longitudinal axis of the piers. He illustrated by diagrams, how in a certain bridge such groynes constructed at a cost of Rs. 8,000/- saved a possible expenditure of Rs. 1.5 lakhs that would have otherwise been necessary.

MR. Ali Ahmed regretted that the Paper was lacking in details. He felt surprised that the H. F. L. taken for the design was considerably lower than the observed flood level that caused the failure of some of the piers. If the bridge site was on or near an existing road, there should not have been any difficulty in obtaining correct hydraulic data. A long time (over 3 years), had been taken in constructing the bridge up to the superstructure

level. If the work including superstructure had been completed in sections in each working season, the failure of piers would have been avoided.

The Author had stated in para 3 of the Paper that "the best way of dealing with slim piers, all of which had collapsed except two, was to replace them by twin R. C. columns of about 3 ft. diameter each, resting on R. C. bases over the existing masonry foundation blocks and connected rigidly to the R. C. Bridge superstructure with one or two R.C. stays running across the columns at mid-centre". It was not clear in the absence of more details what was meant by "running across the columns at mid-centre." From the plans, it was observed that the longitudinal axis of the bridge and the foundations were not in one vertical plane. This eccentricity in the foundations and substructure needed explanation.

MR. C. G. Kale observed that the remarks of the Author "ordinarily piers are made thick, but the contractors in their endeavour to economise made a special design by dividing the bridge into sections having thin and thick piers", led one to infer that the design was left to the contractor who had to compete with others in the field, prepared flimsy design to keep the cost low, and managed to secure the work. He warned against the danger of allowing contractors to design and quote for bridges and then accepting the lowest quotation, without carefully checking the soundness of the design.

MR. A. W. H. Dean remarked that it appeared extremely odd, if in fact this was the case, that the contractor for the work had been allowed to economise by adopting a faulty design. He would like to know the part of the design for which the contractor was responsible. From the Paper as presented it would appear that the local Engineer had not carefully checked the design, selected the proper site, and fixed the height of the vents with reference to the H. F L. This might be a wrong inference but the facts should, he thought, be given in the Author's reply to the discussion. The phasing of the work had apparently not also been given adequate consideration. It was obvious that the whole work could not be completed in one season. Instead of building the piers and abutments to their full height in the first season, it would have been better if most of them had been brought up a few feet from bed level and the completion of the bridge including the superstructure taken up vent by vent. As an additional precaution, the plum concrete hearting of the piers could have been reinforced by old rails.

The Author had denied the usefulness of any river training but had stated in para 5 (g) of the Paper that "the outcrop of rock on the right side which acted as a spur was also a contributing factor in deflecting the current to the centre. . ." Removal of this outcrop would have trained the river to some extent. While criticising the design, Mr. Dean wished to make it quite clear that he was very grateful to the Author for his Paper as there was no doubt about the great value of reports on failures and the remedies adopted. The importance and urgent need for a Central technical authority which would investigate each case of failure, fix responsibility for all accidents, including accidents caused by the wash out of culverts, and make the lessons learnt available to the other Engineers was apparent. The Railways have an Inspectorate which does this.

MR. W.B. Calder said that bridge engineers should draw more freely on the valuable experience gained by the Irrigation engineers in the construction of weirs. River training, he considered, was very expensive and could often be avoided by proper location and design of bridges.

MR. G.M. McKelvie agreed with Mr. Dean that a Central designs office should investigate every case of bridge failure, examine the technical defects in location, in the interpretation of the hydraulic data, and in the design; and prepare an official record which should be made available to all bridge engineers.

He did not think the designs office should concern itself with fixing responsibility for failures, as it was more important to avoid repetition of mistakes and to disseminate knowledge than to undertake the barren duty of looking for scapegoats.

A hand-book on Road Engineering, Specifications for Roads, and a Code of Practice on Bridges were being prepared in Mr. McKelvie's office for use of all road engineers and he hoped to place portions of these books as they were drafted before subsequent Sessions of the Congress to elicit criticism.

He agreed that the local engineers, who had full knowledge of local conditions, should invariably prepare their own bridge designs and that this important duty should not be left entirely to Engineering contractors although there was no objection to considering contractor's designs when these could be compared with and checked against the designs based on local knowledge.

With regard to Mr. Calder's remarks, Mr. McKelvie observed that an interchange of knowledge between Road and Irrigation

Engineers was certainly very desirable. To achieve this Mr. McKelvie had initiated a proposal to set up a joint library and Information Bureau with the Central Board of Irrigation. If this proposal was accepted by the Government of India (the Central Board of Irrigation had already accepted it) it would be possible for road engineers to draw freely on the valuable experience and knowledge now available to irrigation engineers. In return the collective experience of road engineers would be available to irrigation engineers.

MR. L.A. Freak, the Chairman, congratulated the Author on behalf of the Congress on a valuable Paper which had evoked a great deal of constructive criticism. The failure of the Gambhir bridge in the Punjab, referred to by the Author, was, Mr. Freak considered, not exactly similar to that of the Ajoy Bridge. At the Gambhir bridge, there was an exceptional winter flood before the wells had been fully sunk, and these wells got disturbed. The high flood level was then noticed to be much higher than estimated and, as the siting was in a bend of the river, (which by the way could not be avoided), it was decided that more land spans should be introduced on the outer side of the bend while retaining the original spans on the inner side.

In Mr. Freak's view, it was not always possible, especially in hilly areas, to avoid a bend and to site a bridge on a straight reach. Certain sites become obligatory points for crossing, but with proper river training and careful designing of the bridge structure, the disadvantages of the river bend could be overcome.

Mr. Dean had brought out the salient defects in the design of the Ajoy Bridge which caused the failure of the piers. He endorsed Mr. Dean's proposal that the causes of failures in every province should be investigated and remedial measures suggested.

It was unfortunate the Author was not there to reply to the criticisms but he hoped that his replies would be printed in the proceedings.

AJOY BRIDGE—FAILURE OF MASONRY PIERS—REMEDIAL MEASURES ADOPTED.

DISCUSSION

CORRESPONDENCE.

MR. M. A. Mirza remarked that for a correct appreciation of the different factors that had contributed to the failure, a sketch should have been appended showing the position and direction of the collapsed piers. He understood from the Author's descriptive detail that there was no uniformity in the positions occupied by the debris.

He did not agree with the Author that the reason for the failure of the thin piers was due to the obliquity of the current, the extra depth of flow, and the eddies caused by the disturbed motion of the water. When a pier is submerged, it is in a state of *static balance* except for the additional forces on the upstream side due to afflux, velocity head, and impact by wave action. These additional forces are generally so small as hardly to interfere with the stability of the structures. Eddies are also effective only if they disturb the foundations and cause settlement. In the present case, the foundations being on rock have remained intact. According to the Author's theory, piers Nos. 5, 12, and 14 should also have failed as in addition to the action of other forces common to the other failed piers, these had to withstand much greater and varied forces caused by the collapse of the neighbouring piers.

In a similar case of failure of a culvert he had investigated, the piers constructed to heights varying from 4 ft. to 10 ft. had all fallen when the flood water overtopped the tallest pier. It was found that the failure was due to insufficient vertical bond between the courses, particularly at about the bed level. During the construction all foundations had in this case been first brought to bed level at the end of one season and from this level work had been resumed in the next season, without ensuring a proper key between the old and new work. If there is no proper bond between the old and new work, water gets into the joints and the combined action of buoyancy and the horizontal forces due to impact cause failure by sliding and overturning. This, he considered, was the reason for the collapse in the case of the Ajoy Bridge.

MR. MD. Farhatullah was of the opinion that when a straight reach of the river above and below the site of the bridge was not available, preventive measures should have been taken

to induce flow parallel to the piers, by removing the obstructions in the bed, straightening the approaches, etc., for at least half a mile upstream and downstream of the bridge. He considered that an additional vent should have been provided on the Jamtara side, where the river curves outwards. For the safety of the thick piers not replaced by R. C. twin cylinders, he would suggest that these remedial measures should be adopted. For calculating the runoff he would recommend the use of the Hyderabad formula

$$D = 1700\, M^{(0.92 - 0.0714 \log M)} \text{ cusecs.}$$

where M is the catchment in square miles. This formula had given satisfactory results in Hyderabad

MR. J. T. Mehta felt that the thin piers had not been designed for non-axial flow and consequent side-thrust, and that the superstructure, even if completed before the heavy floods, would not have helped in preventing the failure. He would prefer a bridge sited above or below the present location in a straight reach of the river as he thought the cost of diverting the road would have been less than the cost of repairing the damage caused to the bridge.

Since the publication of the paper, and the discussions, the Editor has seen a report by the Indian Waterways Experimental Station, Poona, which is based on the results of model experiments on the failure of the Ajoy Bridge carried out at the Research Station. The report is published as Appendix A on page 81 with the kind permission of the Director. A site plan is attached to the report. The conclusion arrived at by the Research Station is that as the bridge was sited at a curve, the current along the bed was flowing at a different angle from that at the surface and the failure was due to oscillation of the piers caused by these partially opposing and pulsating forces.—*EDITOR*.

(Mr. H. K. Nivas has not found it convenient to reply to the comments on his paper recorded at pages 101 to 104, Volume IX—Section 2.—EDITOR.

APPENDIX A

Extract from the Annual Report (Technical) of work done at the Central Irrigation and Hydrodynamic Research Station, Poona, for the year 1942-43.

FAILURE OF PIERS OF THE BRIDGE UNDER CONSTRUCTION OVER THE AJOY RIVER IN THE SANTAL PARGANAS, BIHAR, DURING THE 1942 FLOODS.

Mr. Murrell, Additional Chief Engineer, P. W. D., Patna referred the case of the failure of certain piers of the Ajoy Bridge during the 1942 floods to the Director.. The bridge was under construction and the superstructure had not yet been added, that the piers were not stabilized, and were therefore liable to fail. According to his report—see plate IV:

> "The rock at piers 14 and 15, and at the abutment pier No. 16, and the high land between the rock and the right bank caused an area or pocket of sheltered water. When the flood is very high, the volume of this sheltered water is very great. During the high flood which occurred on 9-8-1942, when the level reached R.L. 473·26 on the Jamtara side and 474·76 on the Dumka side—thus exceeding the previous H.F.L. by about 4 ft.—the main flow came along the right bank, which deflected it towards the centre of the bridge. Pier No. 15 was thrown towards the right bank. Piers No. 10, 11 and 13 were thrown towards the right bank and also downstream, as the water of the whirlpool at each of these piers was moving partly towards the bank and partly downstream. Similarly piers 4 and 6 failed. The conditions of flow indicated serious throttling of discharge during a high flood."

Details of catchment

Catchment Area	..	..	1210 sq. miles
Length of river : ..	..	..	66 miles
Average width 1210 :- 66	..	..	18·5 miles
Maximum width	..	..	34·0 miles
Average to Maximum width		..	0.55
Form Factor	..	..	0 594

$$\text{Maximum flood runoff} = (0{\cdot}594)^{0{\cdot}25} \times \frac{7000\,A}{\sqrt{A+4}}$$

$$0{\cdot}878 \times 243{,}000 = 213{,}400 \text{ cusecs}$$

In this case the previous highest recorded flood amounted to 116,000 cusecs; but in the record flood of 1942 the water level rose 3·9 ft. higher than the previous highest recorded flood, and was estimated to be 210,000 cusecs. This is in very close agreement with the Poona Station formula.

Under the conditions of this flood there was instability of flow. Similar instability of flow occurred at the tails of piers at Ferozepore (Punjab) shortly after construction and led to their failure due to fluctuating differences of pressure on the two sides of some of the elongated pier tails, and the piers oscillated backwards and forwards with increasing amplitude before they finally sheered off and fell over. This occurred though the angular force of flow was small.

In the case of Ajoy Bridge, some of the piers were carried downstream by the current, some falling to the left and others to the right. This was partly due to the current at the bed flowing at a different angle from that at the surface, and partly to non-axial flow ; but *failure was due to oscillation.*

The protecting rock on the right bank was possibly one cause of the cross flow above the bridge; but a more probable explanation was that the maximum flow along the outside of a river curve occurs at the "dominant discharge", which is generally of the order of half the maximum flood, say, 110,000 cusecs in this case; and experience shows that when the discharge increases above the dominant discharge, the line of maximum flow begins to move towards the inside (convex) bank of the river—*i.e.*, to short-cut across—so that when the maximum discharge occurs, the line of maximum flow may be over the inner, submerged, bank and a cutoff channel may begin to open. This short-cutting seems to have been the condition at the peak of the flood, and there must have been return flow at places along the right, concave, bank. So, though cutting away the rock protection would improve matters during normal floods, it would not affect the short-cutting tendency during floods of greater than 170,000 cusecs.

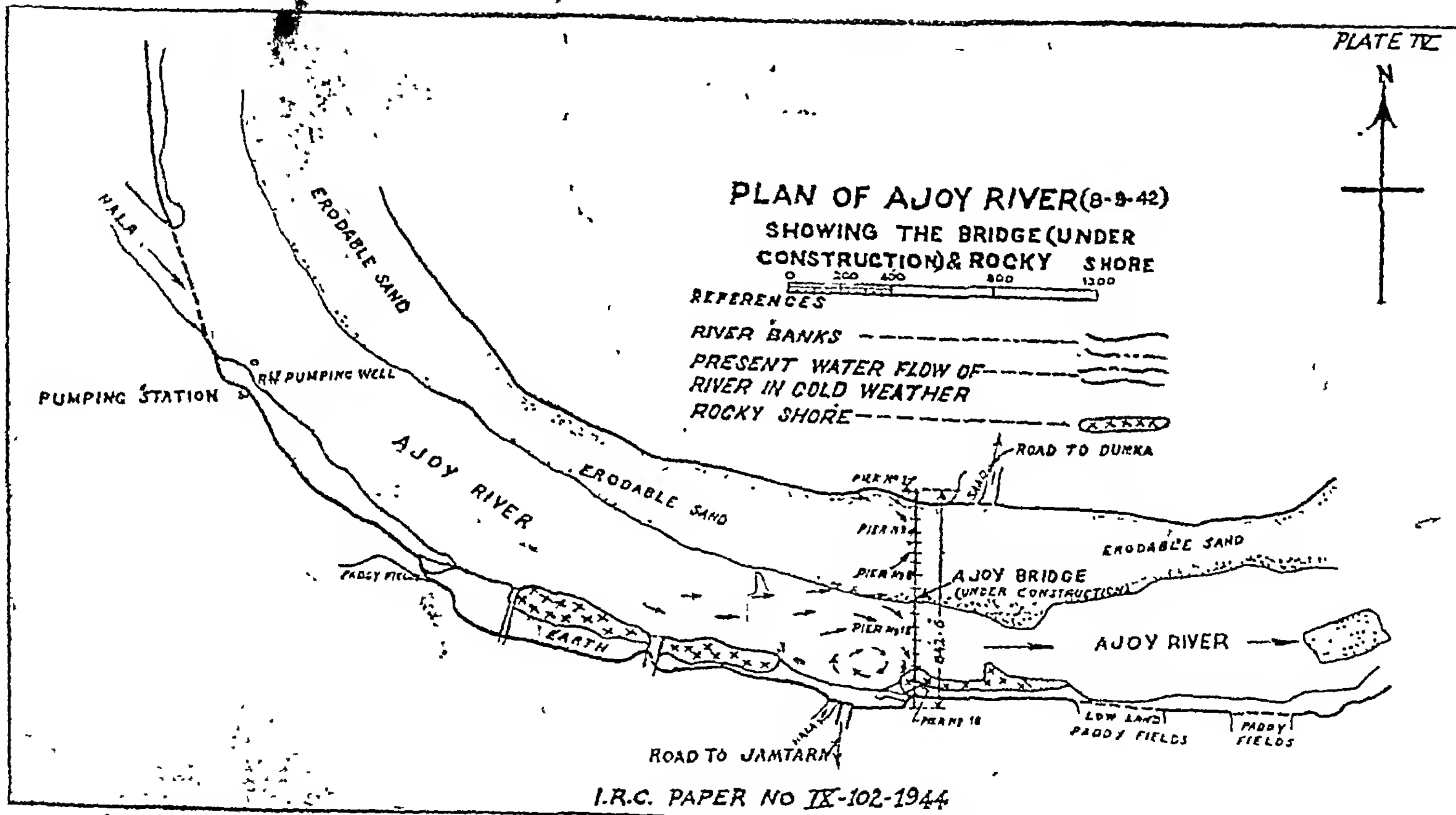


PLATE IV
N
PLAN OF AJOY RIVER (8-9-42)
SHOWING THE BRIDGE (UNDER CONSTRUCTION) & ROCKY SHORE
0 200 400 800 1200
REFERENCES
RIVER BANKS
PRESENT WATER FLOW OF RIVER IN COLD WEATHER
ROCKY SHORE
NALA
PUMPING STATION
RH PUMPING WELL
ERODABLE SAND
AJOY RIVER
ERODABLE SAND
ROAD TO DUMKA
ERODABLE SAND
AJOY BRIDGE
(UNDER CONSTRUCTION)
AJOY RIVER
EARTH
ROAD TO JAMTARA
LOW LANDS
PADDY FIELDS
PADDY FIELDS
I.R.C. PAPER NO IX-102-1944

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INDIAN ROADS CONGRESS

Classified List of Papers in the Proceedings I to IX

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II. Road Surveys, Design, Layout and Construction.
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I. Roads in General

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3	Some notes on the layout of rural and suburban roads in the Punjab.	R. Trever Jones.	III.	32	10-26	36
4	Optimum weight of vehicles on extra-municipal roads.	K. G. Mitchell.	III.	39	92-105	43
5	Layout of Roads.	R. Trever Jones.	V.	k (ii)	4 (k) to 17 (k) 18 (k) to 43 (k2)	56
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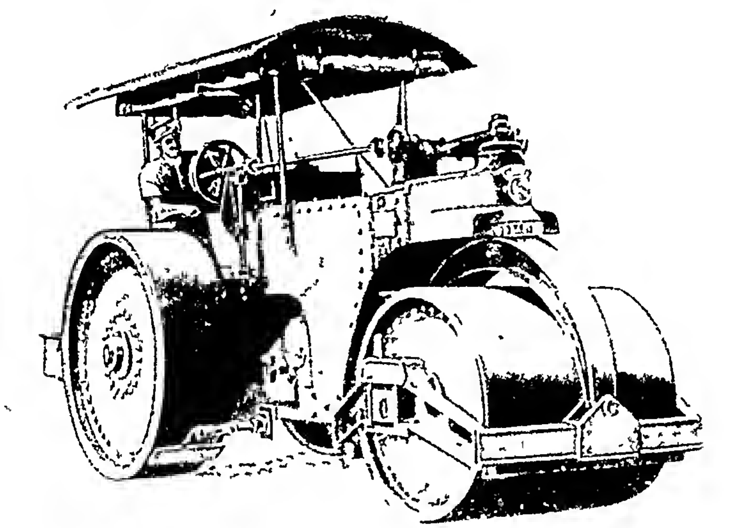

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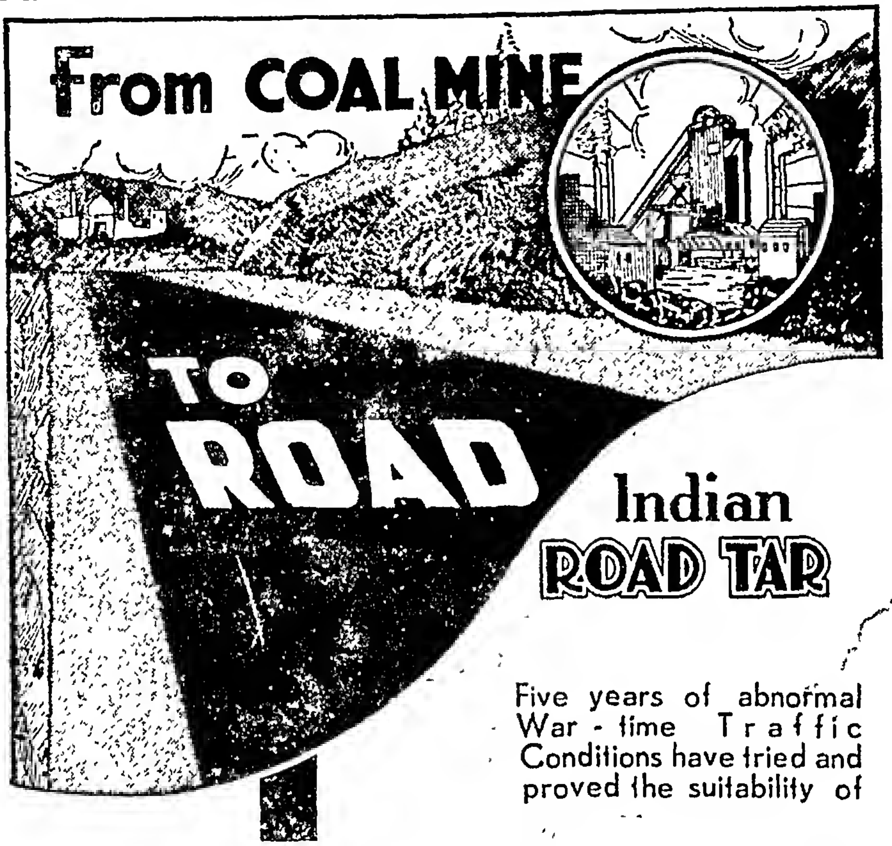

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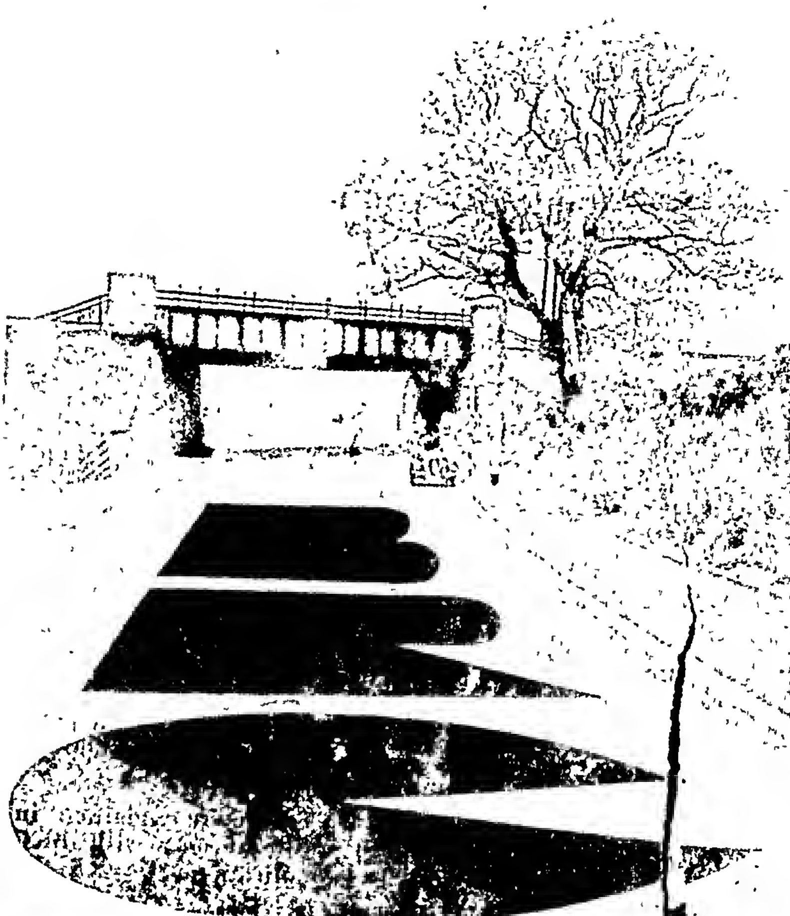

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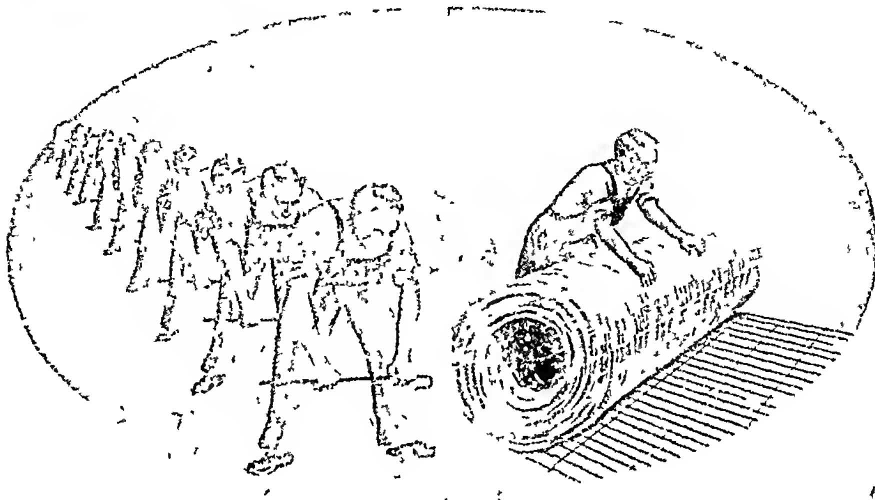

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